MAGNETICAL AND METEOROLOGICAL OBSERVATIONS

MADE AT THE

GOVERNMENT OBSERVATORY, BOMBAY,

1886.

WITH SIX APPENDICES.

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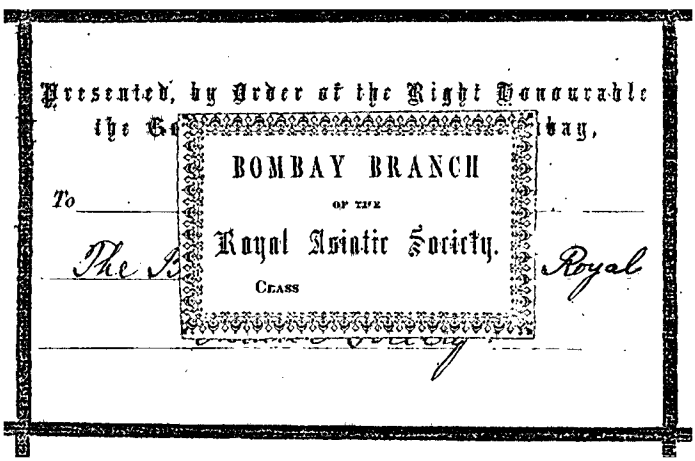

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MADE AT THE

GOVERNMENT OBSERVATORY, BOMBAY,

IN THE YEAR 1886

UNDER THE DIRECTION OF

CHARLES CHAMBERS, Esq., F.R.S.,

WITH SIX APPENDICES CONTAINING ACCOUNTS OF VARIOUS MAGNETIC RESEARCHES.

133498

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1888.

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INTRODUCTION

TO THE

METEOROLOGICAL AND MAGNETICAL OBSERVATIONS,

1886.

Of the series of books entitled "Bombay Magnetical and Meteorological Observations" the present one is the twenty-seventh, extending the record, which before embraced the years 1845 to 1885, up to 1886.

2. The latitude and longitude of the Colába Observatory are 18° 53′ 45″ North and 72° 48′ 56″ East respectively.

3. *Local situation.*—The Observatory is situated at the extremity of a narrow strip of land extending two miles to the south-westward of the Fort of Bombay and separating the harbour and Back Bay. Trap rock, which is very abundant in the ground near and on the surrounding sea-beach, crops up at many places through the red sandy soil which covers the greater part of the Observatory enclosure. During the rainy months of the year, the soil is overgrown with grass, which, however, is quickly burned up when the dry season comes round. The nearest elevated ground is Malabár Hill, which lies on the opposite side of Back Bay, at a distance of four miles, but that which subtends the largest vertical angle, as seen from the Magnetical and Meteorological Observatory, is the southern hill of the Island of Karanja, at a distance of about eight miles across the harbour. The altitude of the highest point of the latter is less than 1° 7′. An idea of the aspect and nature of the surrounding country, and of the exposure of the thermometer shed and anemograph, may be obtained by inspection of the photographs—forming a series of panoramic views all round the compass, together with some near views of the buildings and instruments—which accompanied the "Meteorology of the Bombay Presidency" published in 1878. In the same work will be found a plan of the grounds and buildings of the Observatory, and an index showing the names and uses of the several buildings, and the location of trees of large and small growth.

The buildings concerned with the production of the observations recorded herein are, (1) the Astronomical Observatory and the Anemometer Tower, with a western wing, the greater part of which serves as a computing room, whilst the remainder is partitioned off for a photographic operating room; (2) the Magnetical Observatory with the adjoining Electrometer Tower; (3) the underground Magnetograph room; and (4) the Thermograph Shed, enclosing the thermograph room; to which may be added the old thermometer shed.

4. *Directorship of the Observatory.*—The observations of the year 1886 were taken under the direction of Mr. Charles Chambers, F.R.S.

5. *Observatory Establishment.*—In the Magnetical Department of the Observatory there are one First Assistant, one Second Assistant, three Observers and one Computer; and in the Astronomical Department one First Assistant

and one Second Assistant. These several offices were filled, during the whole of the year 1886, in the manner exhibited in the following statement:—

Name of Officer.	Department.	Name of Office.	Initial.
Vinayek Narayen Nene	Magnetical.	First Assistant ...	V. N.
Crishnaji Ganesh Thakur	Do.	Second Assistant ...	C.
Ganesh Sadashiv Joshi	Do.	Observer	G. S. J.
Vithal Govind Ghaneker	Do.	Do.	V. G. G.
Damodar Waman Sathaye	Do.	Do.	D.
Govind Narayen Vadak	Do.	Computer	G.
Hári Chintaman Karkhanis	Astronomical.	First Assistant ...	H. C.
Parshuram Laxuman Datar	Do.	Second Assistant ...	P.

The initials marked in the last column are those which the respective observers attach to the several observations made by them.

6. *System of observation and reduction and distribution of duties.*—The Astronomical Observatory is furnished with a transit instrument and a sidereal clock, which are used for the determination of local time, primarily for communication to the shipping in the Bombay harbour, and secondarily for communication, by comparison of chronometers three times a week, to the Magnetical and Meteorological Observatory.

Magnetical and meteorological observations are taken and entered in the registration forms every day, without exception, at the hours 6, 10, 14, 16, and 22,—the day commencing at midnight at Bombay (Colába) and being reckoned from 0^h to 24^h. One observer (called the morning observer) takes the 6^h observation, a second one (the day observer) those of 10^h, 14^h and 16^h, a third one (the night observer) that of 22^h, and a fourth is relieved from observing duty for one week; the next week the four observers change round in circular order, and so on week by week. On Sundays and general holidays special arrangements are made to set free all but three members of the staff—one being kept on observing duty, one in charge of photographic instruments, and one in charge of the Astronomical Observatory. All the observers reside on the premises, and they are required to keep a general out-look on the weather during the intervals between their respective hours of observing duty and the next earlier observation hours. Each observer reduces his own observation immediately after the entry of the observation in the register, and the reductions are checked by the observer who next comes on duty: amongst the duties of the day observer are included the calculation of daily averages, and the writing out of the monthly abstracts. These latter consist of tables having the days of the month marked in numerical order in the first column and the hours of the day in order at the head of the columns, and there is one for each magnetical or meteorological element observed. Attendance in the computing room is exacted of the observers, when not actually engaged upon observing duty, as well as of the First Assistant, Magnetical Department, Second Assistant, Astronomical Department, and Computer, for six hours daily, exclusive of a break for rest in the middle of the day. Upon the First Assistant devolves the immediate oversight of general observing, computing and photographic operations. The observations of absolute declination, horizontal intensity, and dip, which are repeated once, twice and twice respectively every week, are distributed amongst the more experienced observers in such a manner that no two consecutive weeks' observations should, as a rule, fall to the same observer. The time of one Assistant is almost entirely absorbed by the photographic operations, the instruments requiring vigilant attention, and the chemical processes demanding much skill and care.

The anemograph is in charge of the Second Assistant, Astronomical Department, who changes the recording paper daily, and tabulates the hourly readings of direction and movement of the wind. The tabulations are checked by the Photographer, between whom and the Second Assistant, Astronomical Department, are divided also the resolution of the tabulations into components and the writing out and checking of wind abstracts, the one performing a set of operations and the other checking them, and so on alternately. The correspondence of the direction record to the actual direction of the vane is frequently checked by turning the instrument to point to the Kennery Lighthouse, the azimuth of which is accurately known. In order to preserve the direction gear in smooth working condition, the fixed toothed wheel is cleaned and oiled—without stopping the instrument—once a week; and every day the direction vane is turned right round the compass once each way, with the object of lubricating both sides of the teeth of the wheel.

All computing operations are systematically performed by one computer and checked, by a repetition of the operation, by another.

7. The eye-observations that are taken five times a day are subsidiary to continuous registrations obtained by means of automatic recording instruments. Of these there are five sets of apparatus,

I. The magnetographs,

II. The barograph,

III. The thermograph,

IV. The pluviograph, and

V. The anemograph,

of which IV is an appendage of III, designed to work with the same light and to trace its curve on the same sheet of sensitive paper. The first four register photographically and the last mechanically.

8. *Instruments and phenomena observed five times a day.*—These are as follows:—

Extent and description of clouds, state of the weather, occasional phenomena, and direction of the wind. From 5 minutes before to 2 minutes after the exact hour.

Thermograph standard thermometer, dry bulb Do. do. wet bulb	At 2 minutes after the exact hour.
Newman's rain gauge (in wet season)... ...	„ 3 „ „
Thermometer in ground 1 inch deep... ... Do. do. 9 inches deep ...	From 5 to 7 „
Newman's standard barometer No. 58 and attached thermometer. Do. do. No. 48 ditto.	„ 7 to 9 „
Grubb's declination magnetometer	At 12 „ „
Grubb's horizontal force magnetometer and its thermometer	„ 14 „ „
Vertical force magnetograph and its thermometer...	„ 17 „ „
Declination magnetograph	„ 18 „ „

Horizontal force magnetograph and its thermometer ... ... } At 19 minutes after the exact hour.
Thermometer attached to barograph ... „ 20 „ „

The vacuum gauges of the magnetographs are read at 10 hours only, the maximum and minimum thermometers in the magnetograph room are read and re-set at 10 hours only, and the 20 inches, 60 inches and 132 inches deep ground thermometers are read at 14 hours only.

Newman's rain gauge is read daily at midnight in the wet season, and the discharges of the syphon of the self-registering rain gauge are read once a day or oftener as required.

9. *Other routine operations.*—(1) The anemograph is supplied with fresh recording papers daily.

(2) Fresh sensitive papers are put upon the recording cylinders of the three magnetographs, of the barograph, and of the thermograph and pluviograph every two days. The papers taken off are developed, fixed and washed, and new ones are prepared by the photographer on alternate days.

(3) The tabulation of anemograms is effected as soon as the papers are available, generally, that is, on the day following that to which the record refers. Barograms, thermograms and horizontal force magnetograms also are regularly tabulated as soon as the registers are available.

(4) Double sets of observations of vibration and deflection are made with the unifilar magnetometer for the determination of the absolute horizontal force weekly, and with the same instrument observations of absolute declination are also made weekly.

Observations of magnetic dip are made twice a week.

The times of vibration of Grubb's declination and Grubb's horizontal force magnetometers are observed once a year; but each of the magnets is disturbed through a large arc (yet less than 1°) once a month, and the nearness of its return to the undisturbed position is recorded.

(5) Transit observations of stars for the determination of time are made generally on Mondays, Wednesdays and Fridays in the dry months: during the monsoon no opportunity is lost of observing the sun or stars when visible. The adjustment of the transit instrument is frequently tested by reference to the fixed collimator mark; the collimation, level, and azimuthal errors are determined from time to time, and whenever the collimator shows a displacement of the telescope, or any considerable discordances appear in the clock errors derived from observations of stars of different north polar distances.

Remarks on the Condition and Adjustments of the Instruments and on the Processes of Reduction.

10. The object of the following description is to make known such special circumstances in connection with the condition, situation and adjustment of the instruments, with the habits of the observers, and with the routine of the processes of reduction, as are necessary to enable the reader to form an independent judgment of the degree of precision attained, and of the weight to be attached to any conclusions that may be drawn from the observations.

I.—METEOROLOGICAL INSTRUMENTS, 1886.

Barometer.

11. *Description.*—The observations which furnished the fundamental data for the construction of the tables of barometric pressure for the year 1886 were taken with a standard barometer by Newman, marked No. 58, the same which has been used uninterruptedly since the establishment of the Observatory. The internal diameter of the barometer tube, marked by the maker on the frame of the instrument, is 0·530 inch. The scale, which is of brass, is moveable, and terminates below in an ivory point which is designed to be set, at each observation, so as just to touch the surface of the mercury in the cistern, and the setting is known to be accurate when the point appears just to meet its image reflected from the mercury. The upper part of the scale, which is divided to twentieths of an inch, has a vernier with slow motion screw, reading to thousandths of an inch, and to it are attached two small brass plates with horizontal lower edges before and behind the tube: the setting of the instrument consists in raising and lowering the vernier until the horizontal plane containing these two edges is tangent to the surface of the mercury in the tube of the barometer, and this is the case when it is just so low, and no lower, that when the eye is raised or lowered no light is seen to pass between the central part of the mercurial surface and the two edges. A thermometer with a cylindrical bulb dipping into the mercury in the cistern is attached to the barometer, and is intended to be read at every observation: but an investigation described in the "Bombay Magnetical and Meteorological Observations, 1871-78," Introduction, pages xlii to xlv, showed that the errors of this thermometer—as measuring the temperature of the mercurial column—were considerable, and since the end of 1884 its use has been discontinued: in lieu of it a thermometer by Murray and Heath (No. 2) divided to half degrees, and with its bulb immersed in a column of mercury held in a glass tube of nearly the same diameter as that of the barometer, was fixed on one side of the metal frame of the barometer at about the same height as the middle of the barometric column, and this has been regularly observed since 1885·0. The error of the new thermometer varies by about a quarter of a degree within the annual range of the temperature of the barometer No. 58, and in adopting a mean error throughout small pressure corrections of $\pm$·0003 are disregarded.

The standard barometer is attached by means of brackets to a flat board which hangs against the wall on the eastern side of the Magnetical Observatory, near the north-east corner of the room, and its cistern has an elevation of 37 feet above the mean sea level at Colába. It was lifted down in May 1866 and the mercury carefully caused to run up to the top of the tube, where it gave the sharp metallic stroke that is indicative of a good vacuum. It is stated in the "Report of the Committee of Physics of the Royal Society, 1840," page 56, where a description is given of a class of barometers of which this is an individual, that the scale is laid off from the zero point from an authentic standard. The tube of the barometer is kept in proper adjustment to verticality.

12. *Error in setting the zero point of the scale, and change of method of observation.*—In the long period that has elapsed since the instrument was mounted (in 1841) there has been a gradual accumulation of scum on the surface of the mercury in the cistern, and the glass cistern became more and more opaque until the reflected image of the ivory zero point of the scale was very obscurely seen, so that the operation of setting the zero of the scale was uncertain to a very sensible degree. For this reason, the method of observation which had always previously been in accordance with the above description, was changed on the 22nd May 1866, so as to avoid the necessity of setting the scale at every observation. The scale was set once for all on that day and the setting

screw then removed; and suitable corrections were thereafter applied for the rise and fall of the mercury in the cistern. These were taken from a table calculated by the formula*

$$\text{Capacity correction} = \cdot 04321\ (b_0 - 29\cdot 943)$$

where b_0 represents the uncorrected reading of the barometer. As the departure of the barometer reading from its mean value very rarely reaches 0·4 inch, which would require a correction of only ·017 inch, it is very improbable that an error of so much as ·001 inch ever occurs from inaccuracy in the adopted value of the relative capacities of the tube and cistern. Since the change was made, the comparability of the observations for showing variations is, therefore, throughout much better secured.

13. *Corrections applied to the observed readings.*—It was stated in the instructions given in the Report of the Committee of Physics (page 56) that the correction for capillary action in barometers of this description is rendered inappreciable by the large diameter of the tube, and consequently no correction for capillarity has ever been applied. Besides the correction for capacity, two others only have been applied; one, invariably from the first, for reducing the observations to what they would have been if the temperature of the mercury had always been 32° Fahr. and that of the brass scale 62° Fahr., and the other, since 1885·0, to remove the discontinuity that would otherwise have been produced in the records by the change of thermometers: the first was taken from Table II. of the Committee's Report, and the last was a constant reduction of the corrected pressure by ·002 inch. The considerations on which the latter correction was based are as follows: (1) the tabulations of the barograph are known to exhibit correctly the diurnal variations of barometric pressure, free from any sensible influence of variations of the temperature of that instrument;† (2) the mean of twenty-four hourly barograph tabulations on any day is taken to correspond to the mean of the same twenty-four hourly pressures observed with Newman's barometer No. 58 and corrected for the temperatures indicated by the old attached thermometer; (3) it does not follow that the mean of the tabulations for the five observation hours (6, 10, 14, 16 and 22) will then correspond exactly to the mean of the observed pressures for the same hours, because the old thermometer does not indicate precisely the actual variations of temperature of the mercurial column: in fact the latter mean pressure was, on the average of all the observation days of the year 1872, ·0008 inch in excess of the former mean pressure; (4) nevertheless the correspondence for the five observation hours was adopted as near enough to identity with the correspondence for the twenty-four hours, and the recorded mean pressures of the years 1873 to 1884 will thus be ·0008 inch in excess of those of the years before 1873; (5) the old attached thermometer and the thermometer No. 2 by Murray and Heath were read together at the five observation hours throughout the year 1883, and the average excess of the former reading over the latter was found to be 0°·62; (6) hence to make the pressures reduced for the readings of Murray and Heath No. 2 correspond to those reduced for the readings of the old thermometer the former pressures must be decreased by $\cdot 0027 \times 0\cdot 62 = \cdot 0017$, or—as the pressures are read and calculated only to thousandths of an inch—by ·002 inch. Thus taking the period before 1873·0 as a standard period, the recorded annual mean pressures of the years 1873 to 1884 will be ·0008 inch too high, and those of 1885 and later years ·0005 inch [$= -\cdot 0020 + \cdot 0017 + \cdot 0008$] too high.

14. *Comparison with the Kew Standard Barometer.*—Indirect comparisons of Newman's barometer No. 58 with the Kew standard have been made through

* The data for the construction of this formula will be found in the "Bombay Magnetical and Meteorological Observations, 1865-70," Introduction, pp. x, xi.

† *See* "Bombay Magnetical and Meteorological Observations, 1871-78," Introduction, pages xxxvii to xlvi.

the mediation of two mountain barometers by Negretti and Zambra, numbered 705 and 711: in Bombay these were both found (in July 1876) to read ·011 inch higher than Newman No. 58, whilst in England they had been found to be ·007 and ·006 inch respectively above the Kew standard: hence Newman's No. 58 reads on the average ·004 inch below the Kew standard. It happens that this is exactly the average amount by which the readings of Newman's barometer have been over-reduced for temperature (*see* Introduction to volume for 1871 to 1878, paragraph 72).

Ground Thermometers.

15. Thermometers with their bulbs at the respective depths below the surface of the ground of 1, 9, 20, 60, and 132 inches are regularly observed, the two former five times a day and the three latter once a day at 14 hours. They are all by Newman, of London, and are divided on brass scales, and the value of one division, approximate range of part of scale exposed above ground, and lengths of that part and of one average degree are shown below for each thermometer:—

Depth of Bulb.	Divided to	Approximate Range of exposed part of Scale.	Length of that Range.	Average length of 1°.
Inch.			Inches.	Inch.
1	1°	30° to 145°	8·19	·071
9	0°·2	70° to 115°	5·20	·116
20	1°	35° to 160°	6·73	·054
60	1°	35° to 160°	6·81	·054
132	1°	50° to 140°	6·44	·072

The 1-inch and 9-inch thermometers are on flat brass scale frames, which lie against wooden posts in the ground, and they have their bulbs in contact with the loose red earth which fills the holes in which they are placed; the 20-inch, 60-inch, and 132-inch thermometers have their lower parts enclosed in brass tubes with ends curving off to a point, and the upper parts are in wooden box frames, to which the brass scales are fixed. The reason why only one observation is made daily of the three deeper thermometers is, that it had been found by hourly observations in 1849, 1850 and 1851, that no appreciable diurnal variation of temperature reached the depth of 20 inches.

The errors of graduation of the ground thermometers are unknown.

The Robinson-Beckley Anemograph.

16. *Description.*—From the beginning of the month of June 1867 was brought into use an anemograph of the kind designed by Dr. Robinson, with improvements by Mr. Robert Beckley, and it remains in action to this day. It was made by Mr. R. W. Munro, and was supplied through the Kew Committee of the British Association, after being tested at the Kew Observatory. In this instrument the arrangements for the registration both of movement and direction of the wind are mounted on one shaft, and the registrations are made on a single sheet of paper, which is changed daily. The essential part of the apparatus for measuring the movement is a vertical spindle, to which cross arms are attached at the top, carrying four hemispherical cups of copper. The cups are attached to their several arms, so that, looking from the central axis, their convex sides are seen turned to the right hand, and the wind, acting with

greater effect upon the concave than on the convex sides of the cups, causes the system to rotate in a right-handed direction. It is the number of these rotations, 140 of which are reckoned to a mile of movement of the wind, that tells us how fast the wind has been blowing; and the number is reduced, by means of wheel-work, 7,000 times before reaching a small cylinder, carrying a brass spiral pencil that traces the movement on the registering paper; this latter is metallic paper of the kind used for pocket-books, and is wrapped round a brass cylinder, which is kept rotating by clock work, and as the paper passes under the spiral pencil, which presses slightly upon it, the black movement trace is received upon it. The wind vane, which consists of a pair of windmill vanes with connecting spindle having an endless screw in the middle, and gearing into a fixed horizontal toothed wheel, is attached to a tube that surrounds the lower part of the vertical movement spindle; to the bottom of the tube is fixed a toothed wheel, which, in communication with other such wheels, conveys the motion of the vane *unchanged* to a small cylinder with spiral pencil, which traces the changes of direction on the register; and it is so arranged that the movement and direction are traced on parallel strips or bands of the same sheet of paper. The heavy parts of the instrument—the direction vane and appendages, and two long brass tubes which connect the instrument proper with the recording apparatus—are supported on friction balls which run in grooves partially filled with oil, thus reducing the friction to a minimum. The instrument is erected on the old Time Ball Tower, at a height of 53 feet above the ground, and 95 feet above the mean sea level, over a platform 12 feet in diameter, which is designed to give ready access to the instrument, and to protect it from irregular currents of wind, glancing from the convex surface of the dome; and it is supported outside by a fixed cast-iron standard, to which is attached, at the top, the toothed wheel, into which the endless screw of the spindle connecting the windmill vanes gears. The centres of each pair of opposite hemispherical cups are four feet apart, and three and a half feet above the platform, and the diameter of the cups is nine inches. The diameter of the vanes is 15 inches, and the breadth of the fans four inches. The register form is printed in red, with lines dividing its length into hour spaces; and its breadth, on the movement side, into five spaces, each representing 10 miles of movement of the wind, and numbered from 0 to 50 miles; and on the direction side into spaces corresponding to 11¼ degrees on each side of the 16 principal directions N.N.E., N.E., &c.....N.N.W., N., which spaces are numbered consecutively 1, 2, &c..... .15, 16.*

17. *Tabulation of Anemograms.*—Numerical tabulations have been made of the movement and direction of the wind during the interval between every two successive hours in the following manner:—the number of miles indicated at the point where the velocity trace cuts a horizontal hour-line being read for two successive hours, the excess of the latter over the former reading (adding 50 if the trace has passed over from left to right of the form) gives the movement for the interval; and the number of the space in which the direction trace lies during the interval is entered as representing the direction. The estimations of movement are made only to the nearest full mile. Should the direction trace not lie all in one space during the whole interval of an hour, then if the change of direction exceed 90° or eight points, the whole observation for that hourly interval is rejected; but if it lie within that limit, the direction is estimated—by an inspection of the movement and direction traces together—whence the aggregate flow of air was the greatest, and this direction is adopted for the full hour. On the average of the years 1871 to 1883, out of 8,754 hours during which the instrument was in action, 3 only had to be rejected, because the direction of the wind varied more than eight points within the hour.

* A more detailed account of the Colába anemograph will be found in the "Bombay Magnetical and Meteorological Observations, 1865 to 1870," Appendix I., page 199.

18. *Method of reduction.*—Hitherto we have had to speak of phenomena liable only to simple increase and decrease of value, and not subject to any change of quality. Such phenomena being properly and completely evaluated by simple numbers, we may apply to the numbers any arithmetical operations, such as averaging, and infer from the results of those operations corresponding properties of the phenomena. But we have now come to a phenomenon which requires two numbers to express it, one representing its amount and the other a varying quality; the first referring to the velocity, and the last to the direction of the wind. Here we may no longer apply arithmetical processes directly and indiscriminately to the observed numbers: but, the subject being one of motion, we must treat them according to the principles of the science of motion. These principles tell us that the motions may be equally well expressed by means of two varying numbers referring to two invariable qualities, as by a varying number referring to a varying quality; and they show us how to obtain either form of expression from the other. The invariable qualities chosen in the present case are the directions north and east, the actual wind blowing in each hour being resolved into north and east components, which may be regarded separately as the velocity of the wind in the invariable direction north or south, and the velocity of the wind in the invariable direction east or west. The resolutions are effected by means of the formulæ :—

$$\text{North component of velocity of wind} = m \cos (n \times 22\tfrac{1}{2}^\circ),$$
$$\text{East component of velocity of wind} = m \sin (n \times 22\tfrac{1}{2}^\circ),$$

where m is the movement observed, and n the number of the direction space under which the wind of the hourly interval is classed. When the sign of either of these calculated quantities is negative, it implies that the wind blows from the opposite direction, *i. e.* from south or west. The calculations are readily made by means of tables to the nearest tenth of a mile of velocity per hour. Having now substituted the two equivalent winds for the real one, we may with propriety proceed to combine together numbers of observations by algebraical addition and averaging, treating the north and east components of the wind each by themselves. The averages thus found from the observations of any given period will represent the velocity with which the wind must blow from the northward (from the southward if the sign of the average be negative) continuously for the whole period, in order that the total movement of the wind from that direction may be the same as the total movement from the same direction produced by the winds which actually blow, and similarly the velocity with which it must blow continuously from the eastward (westward if the sign of the average be negative).

No corrections have been applied to the anemograph tabulations on account of friction.

Rain Gauge.

19. *Newman's Rain Gauge.*—This instrument is made of copper, and exposes for the collection of rain-drops a circular surface of an average diameter of 12·035 inches, forming the top of a funnel, that carries the rain into a cylindrical vessel below, having a diameter of 5·732 inches: a float of slightly less diameter, so as to rise and fall freely, rests upon the water in this vessel, and having a wholly convex external surface, it allows the rain as it falls to flow off and raise the level of the water and with it the float; to the middle of the float is fixed a wooden rod, graduated with divisions, each of which represents ·05 inch of rain; and the readings of this scale, which are easily estimated to fifths of a division, are made where it is cut by the upper edge of a light brass rod placed horizontally across the mouth of the funnel, but half an inch below the edge of the exposed circular surface; the scale passes through a hole in the middle of the horizontal rod, and is thus kept always in a vertical position.

The range of the scale is from 0 to 4·00 inches, and the readings of the scale have been entered in the meteorological register and the differences been taken for every interval between successive observations: the rain has accumulated in the vessel generally till the reading was somewhere above 2·00 inches, when the water was let out, by means of a brass cock at the bottom, till the reading came down to 0·00 inch. This latter reading was also maintained during intervals of dry weather—when, from evaporation, the scale would otherwise have fallen lower—by pouring small quantities of water into the gauge: the reason of this is obvious, as, if some water were not always retained, the float would sometimes rest on the bottom of the vessel and so cease to perform its function of rising equally for equal increments of rain. The scale on the wooden rod was graduated so as to agree approximately with the data—the diameters of the gauge and measuring vessel—given above. The error of the scale according to which the rod was graduated was less than a thousandth of the whole.

Newman's gauge stands on a large rectangular block of stone, in a position intermediate between the Entrance Gate, the Magnetical Observatory, and the Thermograph Shed, where the altitude of the highest neighbouring object, as seen from the gauge, is about 30°. It is supported by three feet, which are embedded with lead in holes cut in the stone block, and its circular mouth is at a height of 4½ feet above the ground and about 35 feet above the mean sea level.

Barograph and Thermograph.

20. Like the anemograph, the Colába barograph and thermograph were supplied through the Kew Committee of the British Association, after being tested at the Kew Observatory; and they are of like construction with those adopted by the Meteorological Committee of the Royal Society for the seven observatories established by them in the year 1867 in the United Kingdom. An account of these instruments in general, with notes on the peculiarities of the Colába set and on special points in the Colába arrangement of them and utilization of their registrations, will be found in the 1871-78 volume of this series, Introduction, pages xvi to xlvi.

21. *Temperature compensation of the barograph.*—The barograph and its thermometer were heated experimentally on January 30 to February 1, 1886, by means of a coal fire lighted in the copper stove of the magnetograph room; and the processes described in the "Bombay Magnetical and Meteorological Observations, 1871-78," Introduction, paragraphs 73 to 75, were applied to obtain from the registrations of the barograph and readings of its thermometer, before, during and after the heating experiment, the rates at which the temperature ordinates and the barometric pressure ordinates, both expressed in true inches, increase with increase of temperature.

One-hundred and thirty-four equations, embracing data recorded between January $29^{d}\ 10^{h}\ 7^{m}$ and February $1^{d}\ 16^{h}\ 21^{m}$, gave for the amount of motion of the compensation stop *per* degree of temperature ·00494 inch; and the same number of equations gave for the motion of the image of the mercury disk *per* degree of temperature ·00471. Practically these are the same numbers (·00497 and ·00470) as were found in 1879 and 1880 [*see* Introduction 1871-1878, paragraph 75], and the compensation remains abundantly accurate.

22. *Thermograph.*—The height of the bulbs of the thermometers above the ground is 10 feet. The cage is placed on one of the most exposed parts of the Observatory grounds and away from any building: it is, however, screened, as well as the thermograph room in which the recording apparatus is placed, by a roomy shed with a planked roof that is everywhere 2 feet above the roofs of the cage and room: the sides of the shed are of the louvre construction on an enlarged scale, with double sheets of zinc enclosing a thick layer of felt substituted for

the wooden laths, and with a vertical distance from lath to lath of one foot: the lowermost two feet of the sides are guarded simply by horizontal iron rods: the roof of the shed is covered with thick felt and then with strong canvas, and the whole of the exterior—sides and roofs—is painted white.

Pressure of Vapour.

23. *Pressure of Vapour and additional capacity of the Air.*—Having obtained from the tabulations of the barograms and thermograms hourly values of barometric pressure, temperature of the air, and temperature of evaporation, the pressure of vapour was calculated for each hour with the aid of a table by the formula

$$f''=f'-\cdot01147\ (t-t')\times\frac{P-f'}{30}$$

in which t and t' denote the temperatures of the air and wet bulb thermometers respectively, f'' and f' the pressure of vapour at the temperature of the dew point and at temperature t', and P the barometric pressure. The values of the pressure of vapour at different temperatures were taken from the following table, the numbers in which have been extracted from Boileau's Collection of Tables:—

Table 1.—*Regnault's values of the Pressure of Vapour at different Temperatures.*

Temperature.	Pressure of vapour.	Temperature.	Pressure of vapour.	Temperature.	Pressure of vapour.	Temperature.	Pressure of vapour.	Temperature.	Pressure of vapour.	Temperature.	Pressure of vapour.	Temperature.	Pressure of vapour.	Temperature.	Pressure of vapour.
o	Inch.	o	Inch.	o	Inch.	o	Inch.	o	Inch.	o	Inch.	o	Inch.	o	Inch.
35	·204	43	·278	51	·374	59	·500	67	·662	75	·868	83	1·128	91	1·455
36	·212	44	·288	52	·388	60	·518	68	·685	76	·897	84	1·165	92	1·501
37	·220	45	·299	53	·403	61	·537	69	·709	77	·927	85	1·203	93	1·548
38	·229	46	·311	54	·418	62	·556	70	·733	78	·958	86	1·242	94	1·597
39	·238	47	·323	55	·433	63	·576	71	·758	79	·990	87	1·282	95	1·647
40	·248	48	·335	56	·449	64	·596	72	·784	80	1·023	88	1·324	96	1·698
41	·257	49	·348	57	·466	65	·617	73	·811	81	1 057	89	1·366	97	1·751
42	·267	50	·361	58	·482	66	·639	74	·839	82	1·092	90	1·410	98	1·805

To find the additional capacity of the air the pressure of vapour was deducted from the number in the above table standing opposite to the temperature of the air.

Self-registering Rain Gauge.

24. A description of this instrument also will be found in the Introduction to the "Bombay Magnetical and Meteorological Observations," 1871 to 1878, page xlvi. In 1886 the syphon discharges were received in glass bottles and measured by means of a graduated glass tube, and a marked glass bottle holding exactly half an inch of rain.

25. It was mentioned in former years that the occurrence of the discharging action of the syphon was occasionally liable to some uncertainty—the water at times trickling over the bend of the tube in considerable quantities before the proper discharge commenced. After trial of many modifications in the form of the syphon one has at last been hit upon, which is free from this fault, and by which the tube is, moreover, kept in a satisfactorily clean condition from beginning to end of the monsoon, simply by the washing that takes place in the ordinary automatic discharges. Since November 1884, when the new syphon was brought into use, the discharges have been regular and unfailing

26. To prevent birds alighting upon the funnel, and choking it with their droppings, a conical arrangement of pointed iron spikes surrounding the funnel was attached in 1882, and was found to be effective.

27. *Constants for converting syphon discharges into inches of rainfall.*—As the surface exposed by the rain gauge funnel is 50·286 square inches, an inch of rain contains 823·955 cubic centimeters. With the aid of a cubic centimeter measure,* 412 cubic centimeters of water were poured into a narrow-necked glass bottle, and a file mark was made on the bottle neck at the level up to which the water rose. A glass tube was also graduated by means of the same cubic centimeter measure, so as to read off thousandths of an inch of rain with ease. The bottle is filled as often as there have been discharges from the rain gauge syphon, and the final excess or defect is measured with the graduated tube. The use of the bottle began on 31st July 1879 and continued till the 26th July 1884, when it was accidentally broken. An exact copy of it, which had been prepared beforehand, was then substituted for the original bottle, and this copy is still in use.

28. *Measurement and distribution of syphon discharges.*—The discharges are measured daily, or oftener during heavy rainfall, and are of course always of an integral number. For each measurement the average value of a discharge is attributed to each of the intervals of time, shown on the rain curve, between pairs of successive discharges; and it remains then only to distribute this quantity, for each filling of the receiving vessel, by means of tabulations of the ordinates of the rain curve. When, as is often the case, the rate of fall of the rain at the time of a discharge exceeds $1\frac{1}{2}$ inch per hour, it is necessary to allow for the rain that enters the receiving vessel during the known time (16 seconds) of discharge, the allowance depending on the rate of rainfall, which is easily estimated for this purpose by noting, with the aid of an appropriate paper scale, the inclination of the rain curve immediately after the time of discharge. The aggregate of such allowances is deducted from a day's (or other) measurement before dividing the quantity equally amongst the several intervals.

29. *Determination of scale of rainfall ordinates.*—The factor for converting ordinates of the rainfall curve into inches of rainfall was found by experiments in which a determined weight or volume of distilled water was poured into the receiving vessel, and the change of length of the ordinate produced thereby was carefully measured. In an experiment made on the 4th May, 1887, the quantity of water poured into the vessel was equivalent to ·424 inch of rain, and the change of length of the ordinate ·420 of a true inch; whence the factor is found to be 1·010, which is applicable to all the rainfall registrations of the year 1886.

30. The tabulations are made with the true-inch scale of the thermograph tabulating instrument, using the white line as datum; and the reading of this datum that shall correspond to the reading ·000 of the rain curve, when the receiving vessel has just been discharged, is re-determined whenever the adjustment of the recording apparatus is disturbed. For this purpose an average is taken of a number of measurements for all of which the rain is falling very slowly at the time of the syphon's coming into action and for a short time longer. It is necessary to select such occasions, because at times of heavy rainfall the curve has risen sensibly before the light has had time to make a distinct impression on the sensitive paper. The mode of tabulating is (1) to set the scale on the constant reading corresponding to the white line, (2) to move the sliding piece until the index is set upon the white line, and (3) to move the sliding bar till the index is set upon the curve, and then read the scale. By setting the paper carefully, so that a considerable length of the white line is practically parallel to the lateral motion of the frame, the repetition of the

* Lent by Mr. F. Chambers, whose verification data show it to be accurate to a thousandth of the 100 cubic centimeters which it is designed to measure.

first two operations of tabulation is avoided until many hourly ordinates have been read; and then a new setting of the paper is made for another stretch of the white line.

Description of the Tables of Meteorological Results and of the Processes of Reduction, 1886.

31. *Barometric Pressure.*—In Table I is shown, for every day in the year, the mean of 24 hourly tabulations of the barograph, corrected* to agree with Newman's barometer No. 58;—also the mean pressure for each month and each year, and the excess of each monthly mean above the annual mean for the same year;—the principal features of the annual variation are also indicated at the foot of the table. The maximum and minimum daily pressures in each month are distinguished by being printed in strong figures.

32. *Temperature of the Air, &c.*—The plan of the following tables is the same as that of Table I, but the subjects of them and the sources from which the numbers are obtained and the mode of obtaining them are as stated below:—

Table II.—Temperature of the air: derived from hourly tabulations of the thermograph dry-bulb.

Table III.—Pressure of vapour: derived from hourly tabulations of the thermograph dry-bulb and wet-bulb, and of the barograph; and calculated in the manner described in paragraph 23.

Table IV.—Additional capacity of the air: derived from hourly differences between the pressure of vapour corresponding to the temperature of the air and the calculated actual pressure of vapour.

Table VII.—Velocities of the north and east components of the wind: derived from hourly tabulations from the register of the Robinson-Beckley anemograph.

Table VIII.—Velocity of the wind regardless of direction: derived from hourly tabulations from the register of the Robinson-Beckley anemograph.

Table XI.—Extent of cloudy sky: derived from estimations made at the hours 6, 10, 14, 16, and 22 daily.

33. Tables VI and XII are on the same plan as Table I, except that the entries made in them are aggregates—daily, monthly and yearly—instead of mean values; and they are sufficiently explained by their several headings.

34. *Monthly and annual range of variation of Meteorological Elements.*—Table V shows the extreme limits between which the oscillations of barometric pressure, temperature of the air, pressure of vapour, and additional capacity of the air were confined in each month and in the whole year, and also the ranges of the respective oscillations.

35. The numbers in Table IX are derived from hourly tabulations from the register of the Robinson-Beckley anemograph. The temperatures of the ground given in Table X are derived from the readings of the several thermometers made five times a day as regards the 1 inch and 9 inches deep thermometers, and once a day as regards the 20 inches, 60 inches and 132 inches deep thermometers. The five-day means of Table XIII are derived from hourly tabulations of the barograph (combined with readings of Newman's barometer No. 58) and thermograph: from the measurements in Newman's rain-gauge, and from hourly tabulations from the register of the Robinson-Beckley anemograph. The rainfall of Table XIV is that received in Newman's gauge. In other respects these tables require no explanation beyond their titles, headings of the several columns, and the foot-notes.

* In the manner described in paragraph 54 of the Introduction of the "Bombay Magnetical and Meteorological Observations for 1871 to 1878."

Notes on instrumental changes and on all irregularities or departures from the routine of observation or reduction, 1886.

36. *Robinson-Beckley Anemograph.*—The light stay rods connecting the velocity cups were painted on March 13 and November 19. Wheel of velocity movement was found disconnected from the wheel of the spiral pencil cylinder on November 8 and December 6: it had apparently been deranged by visitors, of whom too many had been admitted at one time. Clock stopped on November 10, owing to the breakage of the suspension cord of the driving weight. The aggregate of all the interruptions of the instrument in the year 1886 was $13^h\ 35^m$: the loss of record was, however, made good by interpolation. To aid in the making of interpolations, it has been customary, whenever the action of the instrument was voluntarily interrupted for more than one hour, to observe the direction of the wind by estimation, and to record the readings of a small auxiliary velocity measurer put up for the occasion. No complete day's records have been omitted in the formation of monthly abstracts.

37. When for any reason the traces furnished by the photographic self-registering instruments are interrupted, and the interruption includes the moments when one or more hourly tabulations should be made, these last are either substituted by the corresponding eye-observations, if the hours should happen to be any of the five regular observation hours, or if special eye-observations were taken for the purpose, or else, if no eye-observations are available, they are interpolated. In the last case, if the interruption lasts for less time than one hour, the interpolation is made on the assumption that the rate of change of the phenomenon from its value at the beginning to its value at the end of the interruption was uniform, providing that the parts of the curve immediately preceding and immediately following the gap were, in appearance, continuations of the straight line connecting the extremities of the gap. If the last condition is not satisfied, or if the gap, taking account of points inserted by means of eye-observations, is of greater length than one hour, the interpolation is made between the next preceding and the next following hourly entries, first, by allowing for the known *normal* rate of change of the phenomenon between those hours in the same month, and then by assuming that any additional change, shown by the difference between the values of the phenomenon at the two extreme hours, has grown at a uniform rate. Interpolated values are entered in the abstract sheets with enclosing square brackets—inserted eye-observations between parentheses.

38. *Barograph.*—No tabulations were obtained for 19^h, 20^h and (21^h) of the 28th April 1886 on account of a stoppage of the clock.

The aggregate of all the interruptions of the barograph in the year 1886 was $3^h\ 43^m$, the number of hourly tabulations lost was 3, but of these 1 was substituted by an eye-observation, leaving only 2 to be interpolated.

39. *Thermograph dry-bulb.*—Occasional, though rare, failure of the bi-hourly stop to act has caused no loss of record.

The aggregate of all the interruptions of the thermograph dry-bulb in the year 1886 was only $0^h\ 8^m$. No hourly tabulation was lost.

40. *Thermograph wet-bulb.*—No tabulations were obtained for 15^h and (16^h) of the 12th June 1886 on account of drying of the muslin covering of the bulb and imperfect capillary action of threads.

Occasional, though rare, failure of the bi-hourly stop to act has caused no loss of record.

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* If not unusually prolonged, the short interruptions caused by the regular changing of photographic papers and by changing of lamps are not included in the above aggregate, nor in the aggregates of interruptions of the thermograph that follow further on.

The aggregate of all the interruptions of the thermograph wet-bulb in the year 1886 was $8^h\ 42^m$, made up chiefly of short intervals of time occupied in cleaning and renewing the muslin coverings of the bulbs and the bundles of threads connecting them with the supply of water. The number of hourly tabulations lost was 2, but of these 1 was substituted by an eye-observation, leaving only 1 to be interpolated.

41. *Self-registering Rain-gauge.*—Tube leading from funnel to receiving vessel found to have slipped aside at $22^h\ 0^m$ on the 17th June 1886, causing the entire loss of the rain that fell between $18^h\ 26^m$ and that time: fall of rain from 16^h to 22^h was interpolated by multiplying the corresponding fall in Newman's gauge by the average proportion (0·943) of the fall in the two gauges. No other hourly tabulations than those of 19^h to 21^h of the 17th June were lost in the year 1886.

II.—MAGNETICAL INSTRUMENTS, 1886.

Kew Absolute Declinometer and Deflection and Vibration Apparatus.

42. A description of this instrument, with which the observations of absolute declination and of horizontal intensity for the year 1886 have been taken, will be found on pages xxxiii to liii of the Introduction to the "Bombay Magnetical and Meteorological Observations, 1865-70"; the description includes also an account of the situation of the instrument, of the nature and routine of the observations taken with it—with examples of observation and computation forms filled up with the figures of actual observations—and of the formulæ of reduction and the constants involved in them.

43. The entries in columns 1 to 17 and 19 of the Tables of Observations of Absolute Horizontal Force are copied directly from the computation form: column 18 is given to show the degree of accordance existing in the determinations from deflections with the deflecting magnet at the respective distances 0·8 foot and 1·0 foot from the deflected magnet; and the numbers in column 21 are the products of those in column 20 multiplied by the constant number ·46108.

44. The description, referred to above, of the observation of absolute declination will render clear the meaning of the numbers entered in each column of the Tables of Observations of Absolute Declination: all of these, except the monthly means in columns 12 and 13, are taken directly from the observation form.

Kew Dip Circle.

45. A description of this instrument, and of the mode of using it, is also given in the Introduction to the "Bombay Magnetical and Meteorological Observations, 1865-70", pages lvi to lix, and the following additional or corrective remarks will make it applicable to the observations of 1886:—

(1) The place of observation has been the top room of the Electrometer Tower, the dip circle having been placed on the same pillar on which the Kew unifilar magnetometer is placed in the regular observations of absolute horizontal force and absolute declination. The reading of the azimuth circle adopted for this place has invariably been 63° 31′. An observation for the verification of this reading was made on the 22nd February 1881.

(2) The two dip needles used during the year 1886 are respectively marked John Dover No. $\frac{2}{81}$, and John Dover No. 2.

(3) The final cleaning of the axles of the needles has throughout been made with a clean silk cloth.

CHARLES CHAMBERS,
Director.

Colába Observatory, October 1887.

TABLES OF RESULTS

DERIVED

FROM THE CONTINUOUS REGISTRATIONS OF AUTOMATIC METEOROLOGICAL INSTRUMENTS

AND FROM

METEOROLOGICAL OBSERVATIONS.

1886.

TABLES OF RESULTS

DERIVED FROM THE

METEOROLOGICAL OBSERVATIONS MADE DAILY AT 6, 10, 14, 16, AND 22 HOURS.

1886.

FIVE-DAY MEANS, AND ANNUAL AND LUSTRAL MEANS.

1886.

D 736—1 R

TABLE I.—Barometric Pressure, 1886.

Height of Barometer above mean Sea-level = 37 feet.

1886. Date.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
	MONTH.											
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
1	30·003	29·921	29·841	29·847	29·752	29·677	29·637	29·727	29·719	29·708	29·830	29·910
2	29·990	·912	·880	**·876**	·727	·691	·625	·690	**·693**	**·658**	·853	·891
3	·979	·915	·907	·856	·747	·711	·641	·747	·746	·658	·877	·926
4	30·029	·910	·907	·810	·781	·674	·684	·769	·834	·748	·888	·954
5	**·057**	·917	·871	·791	·773	·621	·722	·747	·844	·826	·874	·944
6	·027	·930	·874	·786	·777	·672	·748	·741	·813	·864	·871	·934
7	·000	·934	·858	·768	·777	·729	·762	·794	·789	·871	·866	·943
8	·020	·975	·864	·770	·772	·737	·711	·779	·791	·849	·843	·911
9	·041	·981	·940	·770	·766	·732	·644	·725	·796	·812	·801	·882
10	·015	·920	**·984**	·765	·749	·742	·608	·704	·780	·772	**·751**	**·858**
11	29·971	·901	·937	**·737**	·779	**·760**	·615	·711	·782	·765	·809	·870
12	·925	·929	·915	·783	·762	·752	·572	·669	·781	·778	·941	·881
13	·925	·940	·902	·789	·752	·677	·531	·643	·776	·780	·960	·914
14	·960	·914	·880	·770	·729	·585	·603	·679	·792	·763	**·996**	·948
15	·890	·865	·838	·769	·704	·548	·636	·669	·824	·715	·977	·950
16	·899	·927	·836	·805	·739	·532	·637	·672	·805	·704	·943	·958
17	·926	**·984**	·853	·831	·800	**·461**	·663	·721	·766	·737	·916	·976
18	·938	·949	·883	·872	**·803**	·485	·628	·692	·782	·763	·885	·996
19	·924	·924	·857	·876	·743	·567	·603	·648	·780	·760	·881	30·012
20	·901	·938	·805	·836	·758	·605	·644	**·640**	·812	·821	·909	29·992
21	·895	·955	**·788**	·815	·784	·604	·628	·692	**·851**	·821	·940	·974
22	**·863**	·956	·821	·837	·758	·628	·524	·740	·831	·830	·949	·977
23	·890	·938	·837	·849	·702	·654	**·501**	·786	·789	·857	·937	·976
24	·884	·931	·855	·836	·617	·697	·627	**·799**	·792	**·897**	·895	·954
25	·911	·897	·852	·815	**·532**	·689	·724	·738	·814	·817	·889	·974
26	·910	·913	·817	·808	·553	·657	·704	·717	·830	·744	·899	30·006
27	·890	·878	·788	·799	·601	·679	·674	·727	·818	·789	·912	**·035**
28	·886	**·856**	·816	·769	·622	·704	·697	·732	·791	·861	·917	29·978
29	·929		·865	·769	·670	·692	·719	·703	·761	·853	·933	·939
30	·899		·896	·783	·685	·671	·756	·726	·733	·821	·930	·944
31	·894		·829		·689		**·781**	·732		·817		·947
Monthly Mean.	29·944	29·925	29·864	29·806	29·723	29·654	**29·653**	29·718	29·790	29·789	29·896	**29·947**
Annual Variation.	+·135	+·116	+·055	—·003	—·086	—·155	—·156	—·091	—·019	+·020	+·087	+·138

	in.
Annual mean	29·809
The greatest mean daily barometric pressure in the year (that of 5th January) was	30·057
The least do. do. do. (that of 17th June) was	29·461
Difference =	0·596

TABLE II.—Temperature of the Air, 1886.

1886. Date.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
	°	°	°	°	°	°	°	°	°	°	°	°
1	74·4	69·1	79·0	**78·8**	84·1	86·0	79·3	80·2	79·6	79·1	82·5	77·9
2	73·9	**67·4**	78·6	79·1	84·6	86·1	79·1	80·6	76·9	78·6	84·2	77·0
3	73·7	68·5	78·1	79·7	84·1	86·0	82·5	81·5	**76·0**	79·1	**84·3**	76·9
4	74·0	70·3	78·1	80·1	**83·4**	85·4	83·1	81·7	78·2	**78·1**	83·2	77·9
5	**77·0**	72·2	77·9	81·6	83·5	80·9	**83·5**	81·6	80·2	79·0	82·3	77·8
6	76·6	72·6	77·3	81·3	83·4	84·6	83·4	81·8	80·6	79·2	79·7	76·0
7	75·5	72·5	76·1	81·7	83·5	85·1	83·5	81·7	81·3	79·2	78·9	76·5
8	76·0	72·3	77·7	81·0	83·7	85·4	83·1	**81·9**	81·4	80·3	78·7	75·0
9	76·1	72·6	76·1	80·6	83·5	85·8	83·5	81·5	79·5	81·7	79·0	74·4
10	75·2	72·4	**75·0**	81·3	83·4	86·4	79·5	80·4	79·8	82·8	80·1	75·6
11	75·3	73·4	78·6	82·3	84·0	86·0	**77·6**	80·2	81·0	83·2	79·7	76·9
12	74·7	74·9	81·5	81·4	84·4	86·2	77·7	80·7	81·5	82·5	**76·3**	77·2
13	74·5	75·3	83·2	81·5	84·7	86·3	79·3	79·9	81·5	81·1	78·0	76·9
14	72·4	75·5	**84·7**	81·5	84·8	86·2	78·5	78·6	81·8	82·2	79·0	77·2
15	72·0	75·0	82·3	81·4	85·7	**86·6**	80·3	**77·9**	81·0	81·4	79·8	77·1
16	75·1	72·8	80·7	82·5	85·8	84·6	81·7	80·1	80·4	80·4	79·5	76·6
17	75·2	70·6	79·7	80·5	85·5	81·7	82·3	80·4	80·9	80·7	78·8	75·2
18	75·0	70·2	78·4	80·6	85·4	79·2	81·4	80·2	81·2	80·9	78·9	**78·6**
19	74·3	72·5	78·1	80·7	85·2	**78·0**	80·2	80·3	79·4	80·1	78·8	77·1
20	73·4	73·7	79·0	81·8	85·4	82·7	79·0	80·0	79·1	79·2	79·4	76·2
21	71·9	75·3	78·4	81·4	84·4	79·6	80·3	80·2	79·4	79·4	79·5	74·9
22	71·3	76·0	78·7	81·6	84·6	83·3	77·9	80·2	80·6	79·8	80·3	74·5
23	72·7	76·6	77·3	82·9	86·4	81·8	79·2	80·7	82·4	79·4	77·9	73·2
24	72·6	77·8	76·3	83·4	86·8	80·7	81·1	80·0	**82·5**	79·9	77·1	**72·6**
25	71·5	**78·0**	76·8	82·8	**87·4**	82·5	80·7	80·5	81·6	79·4	78·8	72·7
26	**69·9**	77·9	77·6	82·6	87·3	82·6	81·1	81·0	81·7	80·6	79·5	73·9
27	70·1	77·7	78·3	83·2	85·6	80·7	81·3	80·6	81·6	80·8	80·4	74·8
28	70·7	77·9	80·0	**83·9**	85·4	80·9	81·0	80·9	81·4	81·6	80·0	73·5
29	70·4		79·7	83·7	85·4	79·3	79·5	80·7	81·6	**83·5**	79·6	73·3
30	70·3		80·2	83·5	85·9	78·6	79·5	78·9	80·6	83·4	78·5	73·6
31	71·2		79·2		86·1		81·2	78·1		82·9		74·4
Monthly Mean.	**73·5**	73·6	78·8	81·6	**85·0**	83·3	80·7	80·4	80·5	80·6	79·8	75·7
Annual Variation ...	—6·0	—5·9	—0·7	+2·1	+5·5	+3·8	+1·2	+0·9	+1·0	+1·1	+0·3	−3·8

	°
Annual mean	79·5
The greatest mean daily temperature of the air in the year (that of 25th May) was	87·4
The least do. do. do. (that of 2nd February) was	67·4
Difference =	20·0

TABLE III.—Pressure of Vapour, 1886.

1886. Date.	MONTH. January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
1	0·568	0·405	0·671	0·616	0·910	**0·955**	0·898	0·841	0·853	0·903	**0·907**	0·616
2	·593	**·366**	·669	**·591**	·901	·941	·874	·835	·831	·897	·888	·612
3	·598	·373	·670	·630	·851	·939	**·925**	·858	**·820**	·881	·853	·628
4	·618	·379	·693	·630	·869	·951	·917	·859	·852	·863	·793	·580
5	·555	·466	·694	·648	·837	·931	·916	·839	·858	·841	·749	·579
6	·535	·503	·714	·763	·834	**·871**	·923	·840	·854	·852	·662	·570
7	·555	·553	·706	·810	·859	·877	·924	·843	·832	·848	·664	·568
8	·570	·515	·741	·819	·838	·884	·913	·836	·836	·868	·627	·583
9	·535	·490	·616	·781	**·819**	·888	·922	**·826**	·837	·927	·644	**·533**
10	·553	·567	·617	·808	·854	·925	·902	·859	·843	**·973**	·653	·581
11	·552	·628	**·551**	·743	·887	·936	·866	·854	·848	·927	·798	·740
12	·585	·641	·628	·774	·896	·919	·882	·861	·830	**·826**	·754	·754
13	·618	·685	·699	·719	·889	·927	·892	**·895**	·833	·845	·813	·760
14	·550	**·722**	·716	·714	·880	·917	·875	·887	·855	·915	·852	**·774**
15	·570	·669	·822	·742	·899	·934	·892	·845	·834	·896	·866	·748
16	·701	·628	**·858**	·756	·921	·902	·903	·873	·830	·864	·857	·655
17	**·739**	·529	·797	·807	·916	·942	·900	·864	·826	·860	·853	·628
18	·709	·453	·749	·816	·909	·934	·892	·862	·841	·834	·858	·723
19	·698	·556	·702	·737	·908	·902	·886	·848	·834	·836	·844	·614
20	·623	·604	·700	·811	·917	·951	·883	·847	·860	·846	·862	·581
21	·546	·704	·697	·848	·907	·911	·879	·857	·868	·854	·810	·604
22	·545	·707	·724	·866	·928	·944	**·854**	·883	·912	·865	·728	·634
23	·589	·620	·696	·888	1·006	·942	·864	·874	·938	·831	**·602**	·652
24	·592	·602	·630	·895	·011	·924	·887	·854	·933	·862	·662	·638
25	·499	·678	·629	·895	·046	·934	·889	·855	·929	·846	·712	·634
26	**·426**	·625	·686	·891	**·048**	·935	·868	·859	·935	·888	·789	·644
27	·432	·633	·741	**·916**	0·922	·915	·865	·857	**·947**	·885	·792	·648
28	·507	·701	·760	·910	·922	·899	·865	·868	·939	·889	·757	·624
29	·496		·809	·909	·930	·885	·863	·868	·935	·920	·712	·603
30	·455		·754	·895	·954	·878	·862	·849	·926	·941	·648	·592
31	·558		·731		·938		·868	·851		·895		·620
Monthly Mean...	**0·570**	0·571	0·706	0·788	0·910	**0·920**	0·889	0·856	0·869	0·877	0·767	0·636
Annual Variation ...	—·210	—·209	—·074	+·008	+·130	+·140	+·109	+·076	+·089	+·097	—·013	—·144

	in.
Annual mean	0·780
The greatest mean daily pressure of vapour in the year (that of 26th May) was	1·048
The least do. do. do. (that of 2nd February) was... ...	0·366
Difference=	0·682

TABLE IV.—Additional Capacity of the Air, 1886.

1886. Date.	MONTH. January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
1	0·290	0·307	0·326	0·374	0·263	0·289	0·102	0·191	0·159	0·090	0·207	0·345
2	·247	·309	·315	·406	·288	·308	·121	·211	·095	**·083**	·291	·319
3	·237	·337	·294	·387	·321	·307	·187	·217	**·077**	·114	·327	·305
4	·227	**·371**	·276	·409	·276	·270	·216	·222	·115	·099	·347	**·383**
5	·381	·334	·268	**·441**	·313	·124	**·232**	·240	·175	·152	·358	·381
6	**·388**	·306	·225	·313	·310	·321	·220	·246	·191	·148	·358	·334
7	·332	·249	·197	·275	·290	·332	·223	·239	·236	·151	·330	·352
8	·332	·282	·209	·243	·320	·339	·222	**·254**	·238	·169	·359	·293
9	·372	·315	·286	·267	·332	**·349**	·228	·251	·173	·156	·354	·324
10	·326	·233	·257	·265	·292	·335	·107	·182	·176	·149	**·380**	·307
11	·334	·198	·437	·366	·283	·306	·081	·179	·210	·212	·217	·187
12	·283	·233	·466	·304	·288	·334	**·067**	·189	**·246**	**·286**	·157	·180
13	·237	·197	·447	·361	·307	·331	·109	·126	·244	·219	·149	·166
14	·246	**·163**	**484**	·368	·319	·337	·099	**·092**	·233	·188	·140	**·164**
15	·220	·204	·289	·335	**·334**	·335	·142	·111	·225	·180	·152	·185
16	·174	·180	**·192**	·359	·317	·288	·181	·153	·210	·176	·149	·264
17	**·135**	·221	·219	·239	·308	·142	·205	·175	·230	·189	**·131**	·251
18	·163	·293	·225	·232	·312	·065	·180	·167	·225	·224	·131	·262
19	·152	·249	·264	·315	·305	**·057**	·143	·185	·171	·194	·144	·323
20	·203	·232	·293	·277	·304	·169	·108	·177	·134	·152	·146	·329
21	·240	·179	·276	·228	·278	·098	·156	·174	.137	·151	·202	·266
22	·225	·197	·259	**·214**	·261	·195	·103	·149	·134	·152	·314	·225
23	·217	·303	·245	·240	·255	·144	·135	·174	·172	·173	·360	·166
24	·212	·358	·280	·250	·266	·126	·176	·171	·180	·163	·274	·164
25	·276	·288	·296	·229	·256	·179	·158	·186	·153	·161	·276	·172
26	·309	·335	·264	·226	**·251**	·181	·195	·200	·149	·158	·222	·195
27	·311	·322	·233	·223	·309	·132	·203	·188	·134	·168	·248	·216
28	·251	·262	·266	·254	·301	·155	·194	·187	·133	·192	·270	·204
29	·254		·209	·248	·293	·116	·145	·181	·142	·230	·305	·220
30	·293		·281	·254	·287	·100	·145	·140	·120	·203	·335	·238
31	·208		·271		·313		·197	·113		·233		·236
Monthly Mean.	0·260	0·266	0·285	**0·297**	0·295	0·226	**0·161**	0·183	0·174	0·172	0·255	0·257
Annual Variation ..	+·024	+·030	+·049	+·061	+·059	—·010	—·075	—·053	—·062	—·064	+·019	+·021

	in.
Annual mean	0·236
The greatest mean daily additional capacity of the air in the year (that of 14th March) was...	0·484
The least do. do. do. (that of 19th June) was ...	0·057
Difference =	0·427

Maxima and Minima of different Meteorological Elements, 1886.

TABLE V.—*In which are collected the individual observations in each month of the year, which showed the greatest and the least values of the following elements, viz., Height of Barometer, corrected for Temperature; Temperature of Air; Pressure of Vapour; and Additional Capacity of Air.*

1886.	HEIGHT OF BAROMETER.			TEMPERATURE OF AIR.			PRESSURE OF VAPOUR.			ADDITIONAL CAPACITY.		
Month.	Greatest.	Least.	Range.	Greatest.	Least.	Range.	Greatest.	Least.	Range.	Greatest.	Least.	Range.
	in.	in.	in.	°	°	°	in.	in.	in.	in.	in.	in.
January ...	30·132	29·797	0·335	85·0	63·2	21·8	0·772	0·287	0·485	0·810	0·056	0·754
February ...	·056	·789	·267	86·2	59·5	26·7	·807	·194	·613	·756	·069	·687
March ...	·073	·731	·342	95·4	70·3	25·1	·931	·389	·542	1·146	·077	1·069
April ...	29·948	·678	·270	88·9	72·0	16·9	·960	·365	·595	·772	·097	·675
May ...	·877	·428	·449	91·3	79·5	11·8	1·096	·755	·341	·491	·118	·373
June ...	·818	·362	·456	90·2	76·2	14·0	·012	·772	·240	·520	·020	·500
July ...	·827	·444	·383	87·0	75·4	11·6	·019	·791	·228	·336	·041	·295
August ...	·857	·577	·280	85·3	73·5	11·8	0·964	·754	·210	·356	·031	·325
September ...	·907	·659	·248	86·2	74·6	11·6	1·020	·745	·275	·372	·043	·329
October ...	·944	·585	·359	89·4	75·3	14·1	·042	·727	·315	·491	·049	·442
November ...	30·062	·667	·395	91·3	71·1	20·2	0·972	·436	·536	·822	·053	·769
December ...	·100	·793	·307	86·8	68·8	18·0	·849	·390	·459	·818	·074	·744
Year ...	30·132	29·362	0·770	95·4	59·5	35·9	1·096	0·194	0·902	1·146	0·020	1·126

Rainfall, 1886.

TABLE VI.—*Total Fall of Rain (in inches) as measured by F. Chambers's Self-registering Gauge, the funnel of which is 28 feet above the ground.*

1886. Date.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
					in.	in.	in.	in.	in.	in.	in.	
1							0·85	0·20	0·10	**0·77**		
2						0·01	2·82		**1·28**	0·14		
3						0·06	0·06	0·04	0·78			
4						0·12	0·04		0·07	0·07		
5						1·56			0·02			
6							0·23					
7							0·05					
8							0·15		0·12			
9							0·09	0·01	0·32			
10							**6·20**	0·13				
11						0·01	4·67	0·05	0·01		0·24	
12							4·56	0·03			**0·29**	
13							1·88	0·74	0·01			
14						0·02	4·28	0·63		0·04		
15							1·06	**5·36**		0·39		
16						0·32	0·08	0·13	0·04			
17						[5·70]	0·01	0·08	0·02			
18						**15·11**	0·08	0·29	0·02			
19						6·39	0·38	0·01	1·01			
20					0·01	0·60	1·19	0·12	0·43			
21					0·01	2·94	0·27	0·26	0·73			
22					0·03	0·33	2·40	0·28	0·18			
23						1·08	0·86	0·24				
24						1·36	0·24	0·25	0·72	0·09		
25						0·26	0·62	0·08	0·01			
26					**0·81**	0·43		0·01				
27						0·67	0·03	0·08		0·03		
28					0·02	1·51	0·07	0·02				
29					0·01	1·44	0·31	0·03				
30						1·35	0·53	0·28	0·33			
31							0·02	0·67				
Monthly Total.					0·89	**41·27**	34·03	10·02	6·20	1·53	0·53	
Number of rainy days ...					6	21	**29**	25	19	7	2	

Total fall of rain in the year ... ... 94·47 inches.
Total number of rainy days in the year 109
The greatest daily fall of rain in the year (that of 18th June) was ... ... 15·11 inches.

No rain fell in the months of January, February, March, April and December, nor on any of the days left blank in the above table.

The entry in square brackets—June 17th—is inferred from the simultaneous fall in Newman's gauge.

Mean Daily Velocities of the North and East Components of the Wind, 1886.

TABLE VII.—*Showing the Mean Velocities of the North or South and East or West Components of the Winds which blew on each day of the year 1886.*

In Miles per Hour.

1886.	MONTH.																							
Date.	January.		February.		March.		April.		May.		June.		July.		August.		September.		October.		November.		December.	
	N. or S.	E. or W.	N. or S.	E. or W.	N. or S.	E. or W.	N. or S.	E. or W.	N. or S.	E. or W.	N. or S.	E. or W.	N. or S.	E. or W.	N. or S.	E. or W.	N. or S.	E. or W.	N. or S.	E. or W.	N. or S.	E. or W.	N. or S.	E. or W.
1 ...	3·6 N	0·0	15·0 N	5·5 W	13·8 N	5·0 W	7·8 N	7·7 W	2·2 N	6·8 W	8·6 S	8·0 W	2·9 N	6·3 W	2·5 S	14·2 W	5·2 N	11·0 W	6·0 N	6·2 W	3·4 N	0·7 W	8·3 N	1·6 E
2 ...	4·0 N	1·9 E	14·2 N	0·4 W	11·8 N	5·0 W	9·8 N	4·9 W	5·6 N	7·6 W	5·3 S	11·0 W	2·0 N	11·5 W	3·4 S	16·3 W	5·1 N	4·5 W	3·9 S	2·8 E	3·4 N	1·4 E	6·5 N	3·7 E
3 ...	0·9 N	0·1 W	14·9 N	2·5 W	9·6 N	4·7 W	11·9 N	6·2 W	5·2 N	6·2 W	5·3 S	11·9 W	2·0 S	15·9 W	1·0 S	14·6 W	4·0 S	1·2 E	28·3 S	15·1 E	7·5 N	1·2 E	4·4 N	2·0 E
4 ...	9·2 N	0·3 W	10·9 N	0·4 W	12·2 N	5·9 W	14·1 N	3·8 W	0·9 N	6·5 W	2·4 S	11·9 W	3·0 S	14·7 W	0·4 N	13·4 W	0·3 S	1·3 W	27·0 S	7·0 E	7·6 S	0·5 W	6·8 N	7·6 E
5 ...	8·9 N	7·1 E	8·2 N	3·1 E	9·8 N	5·0 W	6·9 N	1·8 W	3·1 N	5·0 W	7·9 S	2·7 W	3·4 S	15·6 W	0·3 N	13·0 W	7·3 N	6·4 W	18·6 S	3·4 E	6·6 N	2·3 E	6·5 N	7·4 E
6 ...	7·6 N	7·5 E	6·2 N	0·4 E	7·3 N	6·3 W	7·7 N	3·6 W	4·8 N	5·7 W	0·8 S	5·8 W	3·5 S	11·4 W	0·8 S	10·8 W	3·4 N	6·5 W	14·2 S	0·3 E	8·1 N	2·7 E	4·8 N	1·7 E
7 ...	3·8 N	1·1 E	5·7 N	0·2 W	1·6 N	3·2 W	0·8 S	3·1 W	4·9 N	7·1 W	1·8 N	7·4 W	4·2 S	8·1 W	1·0 N	8·6 W	0·5 S	8·4 W	8·2 S	1·4 W	6·6 N	3·6 E	4·8 N	5·4 E
8 ...	8·5 N	2·7 E	12·4 N	2·9 W	1·6 S	6·0 W	0·1 S	4·9 W	3·9 N	7·4 W	3·0 N	8·0 W	2·9 S	9·4 W	0·5 N	6·6 W	0·4 N	12·5 W	1·4 N	5·5 W	7·4 N	3·9 E	7·2 N	2·6 E
9 ...	9·3 N	7·3 E	12·4 N	2·6 W	6·1 N	6·3 W	4·7 N	6·3 W	1·1 N	6·9 W	5·6 N	7·6 W	4·0 S	13·1 W	3·0 N	9·5 W	1·6 N	8·3 W	5·3 S	2·0 W	8·7 N	3·4 E	7·2 N	1·2 E
10 ...	5·7 N	3·5 E	6·6 N	2·0 W	8·1 N	2·5 W	4·3 N	6·7 W	2·5 N	6·8 W	8·0 N	5·8 W	0·2 S	12·5 W	1·5 N	3·6 W	1·9 S	0·4 W	4·6 N	2·3 W	9·4 N	2·4 E	8·6 N	0·6 E
11 ...	4·9 N	3·9 E	7·2 N	1·0 W	10·7 N	1·3 W	5·7 N	5·6 W	1·1 N	6·1 W	1·1 N	6·8 W	2·1 S	12·9 W	2·1 S	1·7 W	0·5 S	7·2 W	7·8 N	2·2 W	3·0 S	11·3 E	5·7 N	0·4 E
12 ...	0·7 N	2·6 E	5·2 N	0·6 W	8·2 N	1·0 E	8·7 N	7·9 W	0·8 S	6·5 W	1·3 N	8·5 W	4·0 S	5·9 W	5·5 N	2·2 W	0·6 N	10·4 W	13·1 N	4·6 W	0·1 S	4·9 E	5·6 N	0·3 W
13 ...	3·2 N	0·3 E	1·3 N	0·2 W	4·7 N	0·5 E	9·2 N	5·7 W	1·0 S	7·6 W	1·2 N	7·5 W	5·3 S	22·0 W	5·9 N	5·2 W	0·8 S	8·4 W	9·9 N	2·9 W	0·0	0·7 W	1·7 N	0·1 E
14 ...	12·9 N	1·4 W	0·4 N	0·0	1·7 N	0·6 W	8·7 N	4·8 W	1·0 S	7·1 W	2·7 N	8·4 W	5·3 S	20·2 W	5·4 N	8·6 W	3·0 S	2·6 W	3·7 N	0·8 E	0·0	3·4 W	7·6 N	2·6 W
15 ...	6·4 N	0·3 W	5·3 N	4·2 W	0·6 S	0·3 E	9·8 N	7·1 W	6·5 S	8·3 W	0·0	7·9 W	4·9 S	23·9 W	7·1 N	15·1 W	4·2 S	2·6 W	4·7 N	1·7 E	7·2 N	5·9 W	7·1 N	1·9 W
16 ...	4·0 S	0·3 E	10·8 N	5·6 W	2·8 S	3·7 W	9·6 N	6·5 W	10·6 S	8·4 W	0·0	5·3 W	0·0	20·4 W	0·7 N	11·2 W	1·9 S	2·8 W	2·7 S	1·5 E	9·1 N	6·1 W	9·4 N	1·6 W
17 ...	0·9 N	1·2 W	13·1 N	5·0 W	5·6 N	5·5 W	8·1 N	6·0 W	1·7 S	7·1 W	4·7 N	11·0 W	0·3 N	18·0 W	2·7 N	14·9 W	3·8 S	3·7 W	11·6 S	2·2 E	8·3 N	3·0 W	5·6 N	0·0
18 ...	4·2 N	2·6 W	11·9 N	2·3 W	14·1 N	7·2 W	3·9 N	6·5 W	0·8 N	4·8 W	10·4 N	11·3 W	0·3 N	17·4 W	8·1 N	20·1 W	5·0 S	1·1 W	17·3 S	5·6 E	5·5 N	3·1 W	5·9 N	4·3 E
19 ...	6·0 N	0·9 E	9·1 N	1·7 W	16·7 N	5·5 W	10·7 N	7·0 W	6·1 N	6·5 W	3·8 S	6·7 W	1·5 S	18·3 W	5·2 N	20·5 W	0·4 N	2·2 W	17·1 S	2·5 E	6·4 N	5·0 W	4·3 N	4·0 E
20 ...	12·2 N	2·3 W	4·1 N	1·7 W	9·5 N	6·2 W	11·5 N	5·8 W	2·2 N	5·7 W	7·9 S	13·8 W	2·7 S	18·0 W	0·0	19·0 W	2·3 S	2·5 W	11·3 S	2·9 E	6·5 N	2·5 W	5·0 N	4·7 E
21 ...	6·9 N	1·3 W	0·1 N	0·1 W	1·1 N	5·6 W	7·2 N	8·2 W	4·8 N	1·1 W	9·1 S	10·9 W	0·8 S	20·3 W	4·4 S	19·7 W	3·2 N	8·0 W	8·9 S	0·6 E	1·8 N	0·5 E	4·6 N	1·6 E
22 ...	2·3 N	0·0	2·7 N	0·4 W	0·7 S	4·6 W	0·5 N	4·6 W	2·0 N	2·4 W	13·2 S	14·2 W	0·5 N	25·8 W	3·9 S	18·0 W	2·1 N	2·6 W	8·7 S	1·8 W	5·3 N	5·0 E	5·9 N	0·0
23 ...	0·7 N	2·2 E	6·8 N	2·4 W	5·1 N	6·4 W	1·7 S	5·5 W	0·5 N	7·3 W	13·0 S	10·9 W	9·7 S	26·1 W	5·8 S	18·0 W	5·9 N	4·5 W	1·3 N	4·7 W	4·4 N	4·4 E	8·6 N	1·6 W
24 ...	7·4 N	1·1 W	6·9 N	2·7 W	6·2 N	6·2 W	2·6 S	5·4 W	0·9 S	7·6 W	5·9 S	11·7 W	2·5 S	22·0 W	3·4 S	18·7 W	9·7 N	6·8 W	5·0 N	4·5 E	6·5 N	1·3 E	7·4 N	0·5 W
25 ...	11·0 N	3·1 W	8·6 N	3·7 W	4·0 N	6·1 W	5·0 S	5·0 W	2·8 N	6·8 W	9·1 S	14·1 W	0·8 S	17·1 W	0·4 S	19·4 W	8·9 N	4·2 W	4·9 N	1·4 W	6·8 N	1·4 E	6·0 N	0·2 W
26 ...	16·0 N	2·5 W	8·4 N	3·2 W	6·2 N	5·2 W	0·3 S	5·5 W	3·7 S	7·7 W	5·0 S	16·4 W	2·7 S	16·5 W	0·3 S	18·7 W	11·0 N	6·6 W	2·3 S	3·5 W	6·3 N	1·7 E	3·2 N	0·9 W
27 ...	15·2 N	3·7 W	13·2 N	6·7 W	7·4 N	5·4 W	4·3 S	5·0 W	33·7 S	2·2 E	0·8 N	14·5 W	5·3 S	15·2 W	0·5 N	15·1 W	10·4 N	5·4 W	2·2 N	1·7 W	5·7 N	2·4 E	4·0 N	0·2 E
28 ...	9·2 N	3·0 W	12·9 N	5·4 W	5·4 N	5·5 W	5·9 S	6·0 W	31·0 S	3·7 E	0·4 N	7·4 W	4·5 S	16·7 W	0·5 S	14·9 W	13·1 N	7·3 W	6·7 N	1·1 W	7·0 N	0·4 E	7·3 N	0·2 E
29 ...	10·1 N	2·6 W			5·0 N	6·8 W		5·8 W	22·2 S	6·1 W	1·1 S	1·8 W	1·0 N	14·7 W	3·2 N	12·5 W	15·1 N	6·6 W	2·1 N	3·1 E	5·0 N	0·4 E	6·0 N	0·8 E
30 ...	13·2 N	4·1 W			9·6 N	7·4 W	0·8 S	4·5 W	16·7 S	7·0 W	0·7 N	3·2 W	0·5 N	16·1 W	0·5 N	7·3 W	10·1 N	9·0 W	3·0 N	0·3 W	6·3 N	5·6 E	6·2 N	1·3 E
31 ...	11·8 N	1·9 W			11·8 N	7·6 W			12·8 S	7·8 W			0·5 N	12·2 W	0·4 N	6·5 W			3·7 N	0·8 E			6·2 N	0·2 E
Monthly Mean ...	6·9 N	0·3 E	8·4 N	2·1 W	6·7 N	4·7 W	4·7 N	5·6 W	2·8 S	5·9 W	1·9 S	9·1 W	2·2 S	16·1 W	0·8 N	12·8 W	3·0 N	5·4 W	3·1 S	0·4 E	5·5 N	1·0 E	6·1 N	1·4 E
Annual Variation ...	4·2 N	5·2 E	5·7 N	2·8 E	4·0 N	0·2 E	2·0 N	0·7 W	5·5 S	1·0 W	4·6 S	4·2 W	4·9 S	11·2 W	1·9 S	7·9 W	0·3 N	0·5 W	5·8 S	5·3 E	2·8 N	5·9 E	3·4 N	6·3 E

The Velocities of the Mean Components for the year are 2·7 N. and 4·9 W.

Velocity of Wind, 1886.

TABLE VIII.—*Mean Velocity of the Wind, in miles per hour, without regard to the direction from which it blew, for each Day of Bombay Civil Time : also the Mean Monthly Velocity, and its Variation from the Mean of the Year.*

1886.	MONTH.											
Date.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.
1	7·8	**17·1**	15·2	12·2	9·0	12·8	**8·2**	14·8	12·4	10·2	7·1	11·2
2	7·6	15·8	13·2	13·2	10·9	12·5	12·8	17·0	11·8	10·0	7·8	11·9
3	7·6	15·7	11·8	14·3	10·3	13·0	16·4	14·7	7·1	**33·0**	10·5	8·8
4	10·6	12·6	14·0	**15·7**	8·3	12·5	15·3	13·5	6·8	28·4	10·5	13·2
5	14·5	12·2	11·9	9·3	7·9	14·1	16·2	13·1	10·6	20·0	12·0	**13·5**
6	14·7	8·5	10·8	9·5	9·5	**7·3**	12·3	11·0	8·7	15·5	13·5	9·5
7	8·5	9·0	7·0	9·1	9·4	8·4	10·3	8·9	8·5	9·5	12·6	11·1
8	11·7	13·3	7·7	7·2	8·8	8·7	10·2	**6·7**	12·5	8·7	12·7	10·9
9	14·4	13·2	10·0	8·4	7·6	9·7	13·9	10·2	10·7	8·4	13·1	10·7
10	9·8	8·1	13·0	8·5	7·9	10·5	13·4	7·0	7·2	8·2	11·0	10·9
11	11·4	10·0	12·4	9·0	6·5	9·2	13·6	7·2	8·1	9·8	**17·6**	9·0
12	7·1	7·9	11·8	12·0	6·7	8·8	9·9	7·1	10·5	14·0	10·0	8·8
13	8·0	6·5	8·6	11·2	7·8	9·0	23·2	8·9	8·7	11·8	6·2	8·3
14	14·6	**6·1**	7·4	11·2	7·4	9·2	21·3	12·2	**6·4**	8·2	**5·7**	9·6
15	8·2	7·8	8·8	13·0	10·9	7·9	24·9	17·2	7·7	10·3	9·7	8·4
16	7·2	13·0	**6·7**	12·7	14·3	11·2	20·4	11·5	7·8	7·8	11·3	10·7
17	7·2	15·1	10·1	11·2	8·6	20·7	18·1	15·4	7·7	13·5	9·9	7·7
18	7·2	13·0	16·8	9·3	**6·2**	**21·9**	17·4	**21·7**	8·8	19·7	7·5	12·2
19	8·8	10·7	**18·0**	14·0	10·6	10·1	18·7	21·5	6·8	18·6	9·2	11·1
20	13·2	6·2	11·8	13·6	6·7	16·4	18·5	19·0	6·9	12·4	8·2	11·4
21	9·3	6·7	7·4	11·5	12·3	18·4	20·4	20·6	9·7	10·6	5·9	8·7
22	**6·2**	7·5	6·7	7·6	7·7	19·8	26·1	18·7	8·5	9·9	11·4	8·7
23	8·5	9·0	8·3	**6·7**	9·5	17·7	**28·0**	19·1	9·3	7·0	12·2	9·9
24	10·8	8·5	9·3	7·7	8·7	14·6	22·5	19·4	12·8	12·2	9·6	8·6
25	12·3	10·9	10·5	9·9	10·2	17·3	17·4	19·5	11·2	7·7	9·4	7·8
26	**17·0**	10·1	11·0	8·7	12·0	17·5	17·0	18·7	13·1	**5·5**	8·1	**5·7**
27	15·9	15·4	11·0	11·2	**35·2**	15·2	16·3	15·5	12·2	7·9	9·6	6·7
28	10·9	14·4	10·0	8·7	32·9	12·0	17·6	15·0	15·4	9·3	10·2	8·8
29	11·2		8·6	11·1	23·5	7·6	15·1	13·7	**16·7**	7·8	8·0	8·7
30	14·3		13·9	6·7	19·0	9·2	16·2	9·8	13·7	6·2	11·3	9·5
31	13·7		15·3		15·3		12·3	8·0		8·4		10·1
Monthly Mean.	10·7	10·9	10·9	10·5	11·7	12·8	**16·9**	14·1	9·9	12·0	10·1	**9·7**
Annual Variation ...	—1·0	—0·8	—0·8	—1·2	0·0	+1·1	+5·2	+2·4	—1·8	+0·3	—1·6	—2·0

	Miles.
The Mean Velocity for June to August	14·6
The Mean Velocity for September to May	10·7
The Mean Velocity for the year	11·7
The greatest monthly mean (that of July)	16·9
The least monthly mean (that of December)	9·7
Difference =	7·2
The greatest mean daily Velocity of Wind in the year (that of 27th May) was	35·2
The least do. do. do. (that of 26th October) was ...	5·5
Difference =	29·7

Aggregate and Mean Velocities and Relative Frequency of Different Winds, 1886.

TABLE IX.—*Showing, for the year 1886, the sums of the Velocities, and the Mean Velocities, in miles per hour, of the Winds which blew, in each Month, from each of the sixteen Principal Directions: and also the number of Observations which those sums comprise; the latter numbers indicating the Relative Frequency of the same Wind (as to direction) in the several Months, and of different Winds during the same Month.*

1886.	N.			N.N.E.			N.E.			E.N.E.			E.			E.S.E.			S.E.			S.S.E.		
Month.	Sum of Velocities.	Number of Observations.	Mean Velocity.	Sum of Velocities.	Number of Observations.	Mean Velocity.	Sum of Velocities.	Number of Observations.	Mean Velocity.	Sum of Velocities.	Number of Observations.	Mean Velocity.	Sum of Velocities.	Number of Observations.	Mean Velocity.	Sum of Velocities.	Number of Observations.	Mean Velocity.	Sum of Velocities.	Number of Observations.	Mean Velocity.	Sum of Velocities.	Number of Observations.	Mean Velocity.
	Miles.		Miles.	Miles.		Miles.	Miles.		Miles.	Miles.		Miles.	Miles.		Miles.	Miles.		Miles.	Miles.		Miles.	Miles.		Miles.
January ...	1,021	111	9·2	462	64	7·2	592	76	7·8	1,190	104	11·4	195	22	8·9	369	42	8·8	99	15	6·6	30	5	6·0
February ...	1,024	109	9·4	549	69	8·0	438	65	6·7	267	31	8·6	84	14	6·0	215	36	6·0	7	1	7·0	0	0	0·0
March ...	571	69	8·3	281	42	6·7	185	27	6·9	253	30	8·4	136	23	5·9	146	20	7·3	40	6	6·7	49	11	4·5
April ...	303	45	6·7	355	57	6·2	77	14	5·5	12	2	6·0	69	10	6·9	29	6	4·8	46	11	4·2	107	12	8·9
May ...	79	14	5·6	97	17	5·7	95	10	9·5	28	4	7·0	11	2	5·5	35	3	11·7	141	7	20·1	472	20	23·6
June... ...	30	4	7·5	33	3	11·0	48	6	8·0	131	11	11·9	54	5	10·8	141	14	10·1	110	11	10·0	219	18	12·2
July ...	5	1	5·0	0	0	0·0	0	0	0·0	10	1	10·0	0	0	0·0	0	0	0·0	30	3	10·0	37	3	12·3
August ...	69	18	3·8	33	4	8·2	23	5	4·6	5	1	5·0	10	2	5·0	20	2	10·0	18	3	6·0	96	15	6·4
September ...	248	33	7·5	41	7	5·9	56	8	7·0	69	12	5·7	85	14	6·1	162	17	9·5	289	37	7·8	159	18	8·8
October ...	271	40	6·8	163	22	7·4	317	43	7·4	324	40	8·1	132	14	9·4	438	50	8·8	478	48	10·0	2,026	95	21·3
November ...	363	50	7·3	289	38	7·6	862	104	8·3	1,293	126	10·3	508	48	10·6	269	31	8·7	71	7	10·1	41	4	10·2
December ...	676	97	7·0	424	67	6·3	671	80	8·4	1,688	155	10·9	356	46	7·7	218	26	8·4	52	7	7·4	0	0	0·0
Year ...	4,660	591	7·9	2,727	390	7·0	3,364	438	7·7	5,270	517	10·2	1,640	200	8·2	2,042	247	8·3	1,381	156	8·9	3,236	201	16·1

1886.	S.			S.S.W.			S.W.			W.S.W.			W.			W.N.W.			N.W.			N.N.W.		
Month.	Sum of Velocities.	Number of Observations.	Mean Velocity.	Sum of Velocities.	Number of Observations.	Mean Velocity.	Sum of Velocities.	Number of Observations.	Mean Velocity.	Sum of Velocities.	Number of Observations.	Mean Velocity.	Sum of Velocities.	Number of Observations.	Mean Velocity.	Sum of Velocities.	Number of Observations.	Mean Velocity.	Sum of Velocities.	Number of Observations.	Mean Velocity.	Sum of Velocities.	Number of Observations.	Mean Velocity.
	Miles.		Miles.	Miles.		Miles.	Miles.		Miles	Miles.		Miles.	Miles.		Miles.	Miles.		Miles.	Miles.		Miles.	Miles.		Miles.
January ...	0	0	0·0	26	4	6·5	8	2	4·0	93	16	5·8	142	19	7·5	288	37	7·8	798	73	10·9	2,613	153	17·1
February ...	0	0	0·0	7	1	7·0	0	0	0·0	23	3	7·7	69	9	7·7	330	34	9·7	1,394	113	12·3	2,902	187	15·5
March ...	6	1	6·0	33	7	4·7	13	2	6·5	232	30	7·7	426	49	8·7	1,107	103	10·7	2,486	184	13·5	2,168	140	15·5
April ...	236	20	11·8	274	29	9·4	119	21	5·7	295	31	9·5	518	57	9·1	1,268	119	10·7	2,377	165	14·4	1,469	121	12·2
May ...	1,301	47	27·7	1,339	74	18·1	673	60	11·2	619	77	8·0	956	115	8·3	1,862	175	10·6	705	81	8·7	268	38	7·1
June ...	135	9	15·0	469	31	15·1	1,296	86	15·1	2,296	159	14·4	1,843	169	10·9	1,614	124	13·0	598	53	11·3	171	16	10·7
July ...	0	0	0·0	51	4	12·7	169	16	10·6	4,480	262	17·1	7,083	398	17·8	663	51	13·0	44	4	11·0	10	1	10·0
August ...	10	2	5·0	27	7	3·9	15	2	7·5	1,777	107	16·6	5,569	375	14·9	2,261	155	14·6	395	30	13·2	149	16	9·3
September ...	116	14	8·3	111	15	7·4	110	17	6·5	372	54	6·9	1,419	153	9·3	1,080	103	10·5	1,696	128	13·2	1,150	88	13·1
October ...	1,466	81	18·1	749	63	11·9	119	25	4·8	98	14	7·0	113	17	6·6	485	43	11·3	743	74	10·0	977	75	13·0
November ...	136	6	22·7	0	0	0·0	0	0	0·0	20	5	4·0	95	14	6·8	523	63	8·3	1,104	96	11·5	1,673	128	13·1
December ...	0	0	0·0	0	0	0·0	0	0	0·0	0	0	0·0	15	2	7·5	408	43	9·5	1,079	98	11·0	1,663	123	13·5
Year ...	3,406	180	18·9	3,086	235	13·1	2,522	231	10·9	10,305	758	13·6	18,248	1,377	13·3	11,889	1,050	11·3	13,419	1,099	12·2	15,213	1,086	14·0

Temperature of the Ground, 1886.

TABLE X.—*Showing, for each Month, the Mean Temperature of the Ground, and its Annual Variation, at the respective depths of 1, 9, 20, 60 and 132 inches below the surface.*

DEPTH.	1 INCH.		9 INCHES.		20 INCHES.		60 INCHES.		132 INCHES.	
Month.	Mean Temperature.	Excess over the yearly Mean.	Mean Temperature.	Excess over the yearly Mean.	Mean Temperature.	Excess over the yearly Mean.	Mean Temperature.	Excess over the yearly Mean.	Mean Temperature.	Excess over the yearly Mean.
	°	°	°	°	°	°	°	°	°	°
January	76·0	—5·4	77·0	—4·5	80·6	—2·9	82·9	—1·2	82·7	—0·7
February	75·9	—5·5	76·1	—5·4	87·8	—4·7	81·8	—2·3	82·3	—1·1
March	81·0	—0·4	80·3	—1·2	81·5	—2·0	82·0	—2·1	82·2	—1·2
April	83·5	+2·1	82·6	+1·1	83·5	0·0	83·4	—0·7	82·5	—0·9
May	87·0	+5·6	85·8	+4·3	86·3	+2·8	85·0	+0·9	83·2	—0·2
June...	85·0	+3·6	85·5	+4·0	87·5	+4·0	86·7	+2·6	84·1	+0·7
July	82·2	+0·8	83·0	+1·5	85·4	+1·9	86·1	+2·0	84·9	+1·5
August	82·2	+0·8	82·4	+0·9	84·4	+0·9	84·9	+0·8	84·5	+1·1
September	82·2	+0·8	82·0	+0·5	83·8.	+0·3	84·2	+0·1	83·8	+0·4
October	82·6	+1·2	82·4	+0·9	84·0	+0·5	84·1	0·0	83·6	+0·2
November	81·6	+0·2	81·7	+0·2	84·0	+0·5	84·3	+0·2	83·5	+0·1
December	77·9	—3·5	78·8	—2·7	82·0	—1·5	83·7	—0·4	83·4	0·0
Year ...	81·4		81·5		83·5		84·1		83·4	

Extent of Cloudy Sky, 1886.

TABLE XI.—*Means of Estimations made at 6, 10, 14, 16 and 22 hours daily, the whole Sky being reckoned as 10.*

1886. Date.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1		0·2			1·2	7·2	**10·0**	7·4	9·4	9·8	2·6	
2		0·6			1·6	5·6	10·0	6·0	**10·0**	9·8	3·4	
3					1·8	4·4	9·6	8·4	8·0	9·2	4·8	
4		3·6			**1·0**	6·2	4·2	6·2	9·0	8·2	1·2	
5		0·4			3·0	9·8	**4·0**	6·2	4·4	2·8		
6	0·4	0·6			2·2	3·8	6·6	5·0	6·0	**1·0**		1·4
7	2·6	3·2	1·0		2·8	5·2	5·6	6·2	7·0	3·0		1·8
8	6·4	0·4	4·0		2·6	**1·2**	8·0	**2·8**	6·4	3·4	2·0	3·6
9	6·8		0·8	0·6	2·4	3·2	6·0	8·2	9·4	2·4	4·8	4·8
10	6·0	0·2			2·2	6·6	8·8	7·6	5·2	7·8	8·6	4·8
11	3·4	3·6		1·2	2·0	7·0	10·0	7·6	3·8	6·8	**10·0**	6·4
12	7·6	1·2	1·2	0·4	3·0	5·8	10·0	9·8	3·6	1·6	4·4	1·2
13	8·2	4·2	1·6	3·6	4·0	3·6	9·6	9·4	4·2	4·4	0·8	0·4
14	8·0	6·8	1·2	0·4	3·2	4·6	10·0	**10·0**	3·4	6·8	4·0	0·2
15	6·6	5·6	3·2	0·4	3·0	5·2	10·0	10·0	6·0	9·0	3·8	
16	**9·6**	1·2	1·4	0·2	4·2	9·6	10·0	10·0	3·8	7·8	2·2	
17	8·6	0·4	0·8		5·0	**10·0**	9·2	9·8	6·2	4·6	1·8	
18	8·0	1·2	0·6		5·6	10·0	10·0	9·4	4·8	2·8	1·4	
19	7·0	3·6	0·6		5·6	10·0	10·0	10·0	6·4	3·8	1·4	
20	2·2	**7·2**	1·6	1·6	**9·4**	9·2	10·0	9·4	9·8	9·4	1·4	1·0
21	0·4	3·0	**4·6**	0·6	8·6	10·0	10·0	7·6	9·2	**10·0**		
22	2·2		2·4	1·6	6·8	8·4	10·0	7·8	7·2	6·6		3·2
23	1·6		0·6	**4·4**	6·0	9·8	10·0	7·8	4·2	2·4		7·4
24			1·0	3·4	6·0	9·4	6·8	7·6	8·0	7·4		7·0
25	2·0		1·8	2·0	5·2	8·8	9·0	9·8	**2·4**	3·4	1·0	5·8
26			1·2	2·6	5·8	9·2	9·8	9·2	3·6	2·0	8·6	**9·4**
27				0·8	4·6	10·0	9·2	7·6	3·2	3·2	5·8	7·0
28					1·8	10·0	7·6	8·2	3·0	3·6	2·4	5·8
29	1·8		1·0	2·0	6·0	10·0	9·2	8·0	6·2	6·0	0·6	3·4
30	1·0			0·8	7·6	10·0	9·0	9·8	8·8	4·4		1·8
31	3·2		0·2		8·2		4·2	10·0		4·2		
Monthly Mean.	3·3	1·7	1·0	**0·9**	4·3	7·5	**8·6**	8·2	6·1	5·4	2·6	2·5
Annual Variation.	—1·0	—2·6	—3·3	—3·4	0·0	+3·2	+4·3	+3·9	+1·8	+1·1	—1·7	—1·8

For the days which have no entry, 0·0 is to be understood.

Mean of the months from January to April, November and December ... ... 2·0

Mean of the months from May to October ... ... 6·7

Mean for the year ... ... 4·3

Rainfall, 1886.

TABLE XII.—*Total Fall of Rain (in inches) as measured by Newman's Gauge, placed 4½ feet above the ground.*

1886. Date.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
				in.	in.	in.	in.	in.	in.	in.	in.	
1							0·87	0·21	0·11	**0·79**		
2						0·02	2·97		**1·35**	0·17		
3						0·07	0·07	0·04	0·85			
4						0·12	0·04		0·07	0·10		
5						1·70			0·02			
6							0·23					
7							0·06					
8							0·17		0·13			
9							0·08	0·01	0·36			
10							**6·46**	0·14				
11						0·02	4·85	0·05	0·01		0.29	
12							4·70	0·04			**0·32**	
13							2·01	0·75	0·01			
14						0·03	4·49	0·66		0·07		
15							1·18	**5·79**		0·41		
16						0·36	0·10	0·14	0·06			
17						6·08	0·01	0·10	0·02			
18						**16·10**	0·09	0·32	0·02			
19						6·46	0·42	0·01	1·10			
20					0·01	0·62	1·26	0·13	0·44			
21					0·02	3·09	0·31	0·29	0·72			
22					0·04	0·36	2·54	0·28	0·18			
23				0·01		1·12	0·94	0·28				
24						1·42	0·25	0·24	0·73	0·12		
25						0·26	0·66	0·09	0·01			
26					**0·86**	0·45		0·01				
27						0·73	0·04	0·07		0·03		
28					0·02	1·57	0·07	0·04				
29					0·01	1·45	0·33	0·04				
30						1·42	0·57	0·27	0·35			
31							0·02	0·69				
Monthly Total...				0·01	0·96	**43·45**	35·79	10·69	6·54	1·69	0·61	
Number of rainy days...				1	6	21	29	25	19	7	2	

Total fall of rain in the year ... ... 99·74 inches.
Total number of rainy days in the year 110
The greatest daily fall of rain in the year (that of 18th June) was ... ... 16·10 inches.
No rain fell in the months of January, February, March, and December, nor on any of the days left blank in the above table.

Table XIII.—Five-day Means, 1886.

Number of Five-day Period.	Barometric Pressure.	Temperature of the Air.	Pressure of Vapour.	Additional Capacity of the Air.	Rainfall.*	North or South Component of Wind.	East or West Component of Wind.	Number of Five-day Period.	Barometric Pressure.	Temperature of the Air.	Pressure of Vapour.	Additional Capacity of the Air.	Rainfall.*	North or South Component of Wind.	East or West Component of Wind.
	In.	°	In.	In.	In.	Miles.	Miles.		In.	°	In.	In.	In.	Miles.	Miles.
1 ...	30·012	74·6	0·586	0·276	0·00	5·3 N.	1·7 E.	38	29·717	83·4	0·920	0·225	0·54	3·6 S.	11·5 W.
2 ...	·021	75·9	·550	·350	0·00	7·0 N.	4·4 E.	39	·586	78·5	·883	·093	22·51	3·4 S.	14·7 W.
3 ...	29·934	73·8	·575	·264	0·00	5·6 N.	1·0 E.	40	·633	81·2	·895	·170	1·80	1·2 S.	19·6 W.
4 ...	·918	74·6	·694	·165	0·00	3·9 N.	1·0 W.	41	·585	79·5	·873	·136	5·30	3·0 S.	22·4 W.
5 ...	·889	72·0	·554	·234	0·00	5·7 N.	0·7 W.	42	·704	80·7	·870	·179	1·10	2·5 S.	16·0 W.
6 ...	·903	70·3	·463	·284	0·00	12·7 N.	3·2 W.	43	·740	80·6	·853	·192	0·84	1·2 S.	14·7 W.
7 ...	·910	69·3	·416	·306	0·00	13·4 N.	2·1 W.	44	·766	81·7	·843	·260	0·00	0·3 N.	10·5 W.
8 ...	·947	72·4	·505	·297	0·00	9·0 N.	0·4 W.	45	·690	80·5	·859	·185	0·99	2·8 N.	4·4 W.
9 ...	·921	74·3	·649	·205	0·00	4·1 N.	0·8 W.	46	·686	79·4	·866	·140	7·01	4·8 N.	14·0 W.
10 ...	·930	72·2	·567	·229	0·00	10·0 N.	3·8 W.	47	·701	80·3	·862	·172	0·99	1·8 S.	19·0 W.
11 ...	·944	75·9	·647	·254	0·00	4·1 N.	1·5 W.	48	·743	80·6	·859	·186	0·45	0·8 S.	17·4 W.
12 ...	·877	78·1	·662	·307	0·00	11·4 N.	4·8 W.	49	·715	78·8	·850	·138	2·46	2·9 N.	8·4 W.
13 ...	·888	78·0	·688	·276	0·00	10·1 N.	5·4 W.	50	·805	79·3	·843	·159	0·94	1·2 N.	4·3 W.
14 ...	·917	76·7	·646	·277	0·00	5·0 N.	3·9 W.	51	·786	80·6	·839	·209	0·50	0·0	7·8 W.
15 ...	·874	82·5	·745	·376	0·00	2·2 N.	0·5 W.	52	·793	81·1	·836	·228	0·09	2·7 S.	4·0 W.
16 ...	·837	78·7	·729	·255	0·00	9·4 N.	6·0 W.	53	·811	79·9	·863	·160	2·46	0·6 N.	3·3 W.
17 ..	·836	77·3	·673	·269	0·00	4·2 N.	5·7 W.	54	·809	82·0	·936	·158	0·74	9·2 N.	5·5 W.
18 ...	·839	79·5	·759	·252	0·00	7·8 N.	6·5 W.	55	·730	80·3	·920	·114	1·31	8·1 N.	5·3 W.
19 ...	·836	79·9	·623	·403	0·00	10·1 N.	4·9 W.	56	·793	78·9	·857	·133	0·10	19·3 S.	4·9 E.
20 ...	·772	81·2	·796	·273	0·00	3·2 N.	4·9 W.	57	·795	82·1	·904	·194	0·00	6·4 N.	3·3 W.
21 ...	·770	81·6	·738	·347	0·00	8·4 N.	6·2 W.	58	·740	81·2	·876	·190	0·48	0·8 N.	0·7 E.
22 ...	·844	81·2	·785	·284	0·00	8·8 N.	6·4 W.	59	·799	79·9	·847	·175	0·00	12·7 S.	2·0 E.
23 ...	·830	82·4	·878	·232	0·01	0·3 S.	5·7 W.	60	·821	80·0	·862	·165	0·15	2·2 N.	1·4 W.
24 ...	·786	83·4	·904	·241	0·00	1·9 S.	5·4 W.	61	·836	82·8	·910	·213	0·00	3·8 N.	0·4 E.
25 ...	·756	83·9	·874	·292	0·00	3·4 N.	6·4 W.	62	·873	82·7	·789	·336	0·00	6·6 N.	1·4 E.
26 ..	·768	83·5	·841	·309	0·00	3·4 N.	6·8 W.	63	·814	79·3	·677	·328	0·29	5·8 N.	4·9 E.
27 ...	·745	84·7	·890	·306	0·00	1·6 S.	7·1 W.	64	·963	78·5	·828	·149	0·32	3·2 N.	2·2 W.
28 ...	·769	85·5	·914	·309	0·01	0·6 S.	6·5 W.	65	·906	79·1	·845	·151	0·00	5·7 N.	2·6 W.
29 ...	·679	85·9	·980	·263	0·06	1·8 N.	5·0 W.	66	·914	78·7	·699	·289	0·00	5·9 N.	2·8 E.
30 ...	·626	85·9	·955	·288	0·89	21·5 S.	3·0 W.	67	·920	79·3	·705	·301	0·00	6·5 N.	2·1 E.
31 ...	·688	85·9	·945	·297	0·21	6·9 S.	10·1 W.	68	·930	77·1	·594	·344	0·00	5·8 N.	4·5 E.
32 ...	·698	84·4	·890	·293	1·70	0·3 N.	6·3 W.	69	·893	75·7	·601	·293	0·00	6·7 N.	2·0 E.
33 ..	·703	86·2	·925	·329	0·05	2·9 N.	7·4 W.	70	·930	77·0	·738	·192	0·00	6·3 N.	1·3 W.
34 ...	·519	82·0	·923	·177	29·00	2·3 N.	8·4 W.	71	·990	76·4	·630	·286	0·00	5·1 N.	2·9 E.
35 ...	·638	81·6	·934	·146	6·61	9·8 S.	12·3 W.	72	·977	73·4	·640	·184	0·00	6·2 N.	0·6 W.
36 ...	·684	81·2	·914	·153	4·46	2·8 S.	10·8 W.	73	·969	73·9	·617	223	0·00	5·9 N.	0·5 E.
37 ...	·652	80·5	·898	·145	5·37	0·1 N.	10·3 W.								

* Five-day sums, *not means*.

Meteorological Elements, 1881 to 1885.

TABLE XIV.—*Annual and Lustral Means.*

Year.	Barometric Pressure.	Temperature of Air.	Pressure of Vapour.	Additional Capacity.	Rainfall.*	Wind.	
						North Component.	East Component.
	In.	o	In.	In.	In.	Miles.	Miles.
1881	29·820	80·0	0·774	0·257	73·04	2·0 N.	5·5 W.
1882	29·807	79·1	0·764	0·239	69·23	2·6 N.	5·8 W.
1883	29·812	78·8	0·758	0·237	90·18	1·8 N.	4·7 W.
1884	29·827	78·8	0·756	0·238	75·44	2·5 N.	5·6 W.
1885	29·826	79·2	0·769	0·240	67·91	2·6 N.	5·5 W.
Mean	29·818	79·2	0·764	0·242	75·16	2·3 N.	5·4 W.

*Sums, *not* means.

TABLES OF RESULTS

OF

ABSOLUTE MAGNETICAL OBSERVATIONS,

1886.

B 736—1

Observations of Vibration and Deflection, taken with the Kew Unifilar Magnetometer (No. 23, by Elliott Brothers), for the determination of Absolute Horizontal Force.

1886.

1886. Date.	Civil Time. Mean.	Magnet N. 23a. Time of one Vibration.	Effect of 90° Torsion.	Temperature.	Rate of Chronometer.	Corresponding Mean Reading of L. H. F. Magnetometer. Scale Reading.	Thermometer.	Angle of Deflection of Magnet N. 23 c by N. 23 a at Distance. 0·8 foot.	1·0 foot.	Temperature.	Corresponding Mean Reading of L. H. F. Magnetometer. Scale Reading.	Thermometer.	Observer.	Calculated Results in English Units. Values of m.	Values of X. From Deflections at distance. 0·8 foot ($X_{0\cdot8}$)	1·0 foot ($X_{1\cdot0}$)	Difference. $X_{0\cdot8} - X_{1\cdot0}$	Mean. $\frac{X_{0\cdot8} + X_{1\cdot0}}{2}$	Monthly Mean Values of X.	Monthly Mean Values of X in Metrical Units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	h. m.	s.	sc. div.	°	s.		°	° ′ ″	° ′ ″	°		°								
JANUARY 6	12 19	2·8214	0·78	84·8	+8·5	15·75	83·1	17 43 20	9 0 20	85·4	15·33	83·9	P.	·64594	8·1186	8·1175	+·0011	8·1180		
„ „	15 10	2·8235	0·79	85·0	„	14·69	85·3	17 43 27	9 0 20	85·5	14·83	85·0	P.	·64568	8·1122	8·1113	+·0009	8·1117		
„ 13	11 58	2·8223	0·82	83·5	+9·1	15·54	80·9	17 43 30	9 0 27	83·1	15·22	82·5	G.S.J.	·64564	8·1165	8·1150	+·0015	8·1157		
„ „	15 13	2·8230	0·83	82·1	„	14·97	82·1	17 43 40	9 0 30	83·9	14·88	82·8	G.S.J.	·64552	8·1119	8·1105	+·0014	8·1112		
„ 20	12 4	2·8224	0·80	81·0	+7·6	15·58	79·5	17 44 22	9 0 55	80·2	15·39	80·6	V.G.G.	·64552	8·1132	8·1115	+·0017	8·1123	8·1141	3·7412
„ „	15 13	2·8227	0·82	80·2	„	14·81	80·8	17 44 42	9 1 7	80·0	14·91	81·0	V.G.G.	·64556	8·1107	8·1087	+·0020	8·1097		
„ 27	12 6	2·8209	0·82	77·7	+8·8	16·97	75·4	17 44 17	9 0 50	76·8	16·70	76·6	G.S.J.	·64533	8·1182	8·1167	+·0015	8·1174		
„ „	15 17	2·8209	0·78	78·4	„	15·94	78·5	17 44 32	9 0 55	77·9	16·25	78·0	G.S.J.	·64567	8·1171	8·1160	+·0011	8·1165		
FEBRUARY 3	12 7	2·8207	0·84	75·9	+8·8	17·33	74·4	17 44 12	9 0 45	74·9	17·12	75·5	V.G.G.	·64509	8·1191	8·1180	+·0011	8·1185		
„ „	15 16	2·8208	0·83	78·5	„	16·18	77·9	17 44 45	9 1 0	76·5	16·42	77·1	V.G.G.	·64561	8·1178	8·1169	+·0009	8·1173		
„ 10	11 58	2·8205	0·83	82·1	+8·7	16·68	79·7	17 43 30	9 0 20	79·7	16·27	80·2	G.S.J.	·64554	8·1233	8·1227	+·0006	8·1230		
„ „	15 14	2·8224	0·84	80·1	„	15·20	81·1	17 44 45	9 1 5	79·5	15·30	81·1	G.S.J.	·64558	8·1126	8·1102	+·0024	8·1114	8·1173	3·7427
„ 17	12 8	2·8210	0·81	78·3	+8·5	15·94	77·6	17 44 45	9 1 2	77·2	15·81	78·4	V.G.G.	·64555	8·1165	8·1152	+·0013	8·1158		
„ „	15 18	2·8220	0·83	79·0	„	15·55	78·0	17 45 17	9 1 20	78·6	15·48	78·1	V.G.G.	·64559	8·1107	8·1094	+·0013	8·1100		
„ 24	12 4	2·8221	0·74	86·0	+7·5	15·91	82·9	17 41 52	8 59 27	84·1	15·67	83·6	G.S.J.	·64537	8·1242	8·1242	·0000	8·1242		
„ „	15 15	2·8232	0·68	85·8	„	15·06	85·0	17 42 17	8 59 40	84·9	15·29	84·7	G.S.J.	·64545	8·1186	8·1184	+·0002	8·1185		
MARCH 3	12 6	2·8219	0·72	87·0	+7·8	16·60	83·8	17 40 25	8 58 35	85·1	16·35	84·9	V.G.G.	·64512	8·1302	8·1313	—·0011	8·1307		
„ „	15 24	2·8231	0·72	83·8	„	14·93	85·1	17 42 5	8 59 25	85·1	15·52	85·9	V.G.G.	·64549	8·1176	8·1186	—·0010	8·1181		
„ 10	11 27	2·8221	0·66	83·5	+8·0	16·10	81·6	17 41 50	8 59 27	82·0	15·89	82·2	G.S.J.	·64506	8·1244	8·1242	+·0002	8·1243		
„ „	15 18	2·8236	0·63	82·7	„	14·82	83·0	17 42 57	9 0 2	82·7	15·21	82·9	G.S.J.	·64530	8·1147	8·1143	+·0004	8·1145		
„ 17	12 10	2·8223	0·63	89·9	+8·1	15·02	86·4	17 41 35	8 59 17	88·8	14·80	86·7	V.G.G.	·64585	8·1240	8·1242	—·0002	8·1241	8·1180	3·7430
„ „	15 10	2·8225	0·64	88·2	„	14·15	86·9	17 42 20	8 59 40	88·4	14·28	87·0	V.G.G.	·64603	8·1195	8·1195	·0000	8·1195		
„ 24	12 9	2·8231	0·63	85·9	+7·5	15·71	82·6	17 41 50	8 59 30	84·1	15·69	82·9	G.S.J.	·64522	8·1214	8·1208	+·0006	8·1211		
„ „	15 17	2·8239	0·65	85·7	„	15·03	83·4	17 42 10	8 59 42	84·7	15·29	83·3	G.S.J.	·64528	8·1171	8·1163	+·0008	8·1167		
„ 31	12 14	2·8241	0·66	86·2	+7·9	13·88	84·3	17 43 55	9 0 30	85·9	13·75	85·1	V.G.G.	·64574	8·1094	8·1092	+·0002	8·1093		
„ „	15 20	2·8245	0·64	85·0	„	13·51	84·7	17 45 30	9 1 20	85·8	12·89	85·0	V.G.G.	·64576	8·1018	8·1010	+·0008	8·1014		

1886. Date.	Civil Time. Mean.	Magnet N. 23 a. Time of one Vibration.	Effect of 90° Torsion.	Temperature.	Rate of Chronometer.	Corresponding Mean Reading of L. H. F. Magnetometer. Scale Reading.	Thermometer.	Angle of Deflection of Magnet N. 23 c by N. 23 a at Distance. 0·8 foot.	1·0 foot.	Temperature.	Corresponding Mean Reading of L. H. F. Magnetometer. Scale Reading.	Thermometer.	Observer.	Calculated Results in English Units. Values of m.	Values of X. From Deflections at distance. 0·8 foot ($X_{0\cdot8}$)	1·0 foot ($X_{1\cdot0}$)	Difference. $X_{0\cdot8}-X_{1\cdot0}$	Mean. $\frac{X_{0\cdot8}+X_{1\cdot0}}{2}$	Monthly Mean Values of X.	Monthly Mean Values of X in Metrical Units.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	h. m.	s.	Sc. div.	°	s.		°	° ′ ″	° ′ ″	°		°								
April 7	12 1	2·8235	0·67	89·8	+7·9	15·42	86·8	17 40 30	8 58 55	88·7	15·01	87·5	G. S. J.	·64521	8·1244	8·1233	+·0011	8·1238		
„ „	15 8	2·8247	0·66	89·0	„	13·78	88·1	17 41 22	8 59 22	88·9	14·23	88·0	G. S. J.	·64554	8·1169	8·1156	+·0013	8·1162		
„ 14	12 10	2·8244	0·67	88·6	+8·0	14·28	86·6	17 42 22	8 59 50	88·1	14·22	87·1	V. G. G.	·64549	8·1145	8·1133	+·0012	8·1139		
„ „	15 15	2·8265	0·67	88·2	„	12·77	87·4	17 43 12	9 0 15	88·7	13·45	87·4	V. G. G.	·64570	8·1044	8·1035	+·0009	8·1039	8·1157	3·7420
„ 21	12 1	2·8248	0·63	89·6	+7·7	14·65	86·9	17 41 15	8 59 20	88·6	14·36	87·5	G. S. J.	·64518	8·1178	8·1163	+·0015	8·1170		
„ „	15 23	2·8256	0·59	89·1	„	13·93	87·9	17 41 42	8 59 32	88·5	14·08	88·1	G. S. J.	·64527	8·1137	8·1124	+·0013	8·1130		
„ 28	12 7	2·8243	0·63	92·1	+7·4	14·41	88·9	17 40 25	8 58 52	91·2	14·24	89·4	V. G. G.	·64545	8·1221	8·1210	+·0011	8·1215		
„ „	15 21	2·8255	0·63	91·8	„	13·82	89·7	17 40 45	8 59 2	91·3	14·05	89·9	V. G. G.	·64542	8·1169	8·1160	+·0009	8·1164		
May 5	11 49	2·8248	0·60	92·7	+7·7	14·67	88·5	17 40 0	8 58 42	91·3	14·47	89·0	G. S. J.	·64525	8·1227	8·1214	+·0013	8·1220		
„ „	15 8	2·8261	0·60	91·2	„	13·70	90·0	17 40 40	8 59 0	92·3	13·91	89·8	G. S. J.	·64527	8·1143	8·1132	+·0011	8·1137		
„ 12	12 16	2·8263	0·61	92·8	+6·9	13·51	89·7	17 40 47	8 59 5	92·2	13·54	90·3	V. G. G.	·64533	8·1147	8·1133	+·0014	8·1140		
„ „	15 12	2·8262	0·60	92·1	„	13·43	91·2	17 40 50	8 59 5	93·0	13·51	91·0	V. G. G.	·64534	8·1135	8·1124	+·0011	8·1129	8·1160	3·7421
„ 19	12 6	2·8260	0·62	93·8	+7·5	14·09	90·1	17 40 20	8 58 47	92·7	14·00	90·7	G. S. J.	·64530	8·1176	8·1169	+·0007	8·1172		
„ „	15 24	2·8265	0·59	91·8	„	13·64	80·8	17 40 32	8 58 52	93·0	13·82	90·9	G. S. J.	·64521	8·1133	8·1128	+·0005	8·1130		
„ 26	12 9	2·8247	0·62	92·2	+7·6	14·05	92·9	17 40 22	8 58 52	93·2	13·87	93·3	P.	·64549	8·1195	8·1182	+·0013	8·1188		
„ „	15 0	2·8258	0·60	94·0	„	13·29	93·7	17 40 27	8 58 55	93·5	13·49	93·7	P.	·64558	8·1173	8·1160	+·0013	8·1166		
June 2	12 7	2·8255	0·54	91·8	+7·1	14·23	90·5	17 39 27	8 58 30	92·5	14·05	90·9	G. S. J.	·64497	8·1206	8·1188	+·0018	8·1197		
„ „	15 23	2·8269	0·53	92·4	„	13·45	92·0	17 39 32	8 58 30	93·3	13·67	91·8	G. S. J.	·64493	8·1163	8·1147	+·0016	8·1155		
„ 9	12 34	2·8257	0·56	92·4	+7·3	14·00	89·6	17 39 30	8 58 30	92·8	13·93	90·1	P.	·64506	8·1203	8·1186	+·0017	8·1194		
„ „	15 6	2·8257	0·56	92·0	„	13·77	90·9	17 39 20	8 58 27	93·2	13·85	90·8	P.	·64504	8·1201	8·1182	+·0019	8·1191		
„ 16	11 52	2·8246	0·51	90·6	+7·7	14·63	89·1	17 38 57	8 58 15	91·4	14·54	89·9	G. S. J.	·64496	8·1253	8·1234	+·0019	8·1243	8·1167	3·7424
„ „	15 14	2·8265	0·52	92·6	„	13·91	90·8	17 39 10	8 58 20	92·2	14·21	90·3	G. S. J.	·64488	8·1201	8·1184	+·0017	8·1192		
„ 23	12 13	2·8241	0·55	87·1	+7·8	14·76	85·2	17 39 47	8 58 37	87·4	14·62	85·6	P.	·64472	8·1244	8·1227	+·0017	8·1235		
„ „	15 7	2·8261	0·53	86·0	„	14·10	84·4	17 40 2	8 58 45	86·5	14·35	84·6	P.	·64438	8·1176	8·1160	+·0016	8·1168		
„ 30	12 16	2·8243	0·48	82·9	+8·2	14·83	81·9	17 44 40	9 1 5	82·4	13·94	81·7	G. S. J.	·64507	8·1070	8·1051	+·0019	8·1060		
„ „	15 18	2·8261	0·50	82·6	„	14·04	81·7	17 44 0	9 0 40	82·0	14·29	81·5	G. S. J.	·64494	8·1042	8·1031	+·0011	8·1036		
July 7	12 12	2·8237	0·47	89·4	+8·1	14·69	86·2	17 40 22	8 58 57	89·6	14·67	87·0	V. G. G.	·64542	8·1236	8·1218	+·0018	8·1227		
„ „	15 20	2·8241	0·48	89·5	„	14·07	87·5	17 41 10	8 59 20	90·9	14·42	87·5	V. G. G.	·64579	8·1184	8·1165	+·0019	8·1174		
„ 14	12 4	2·8229	0·45	80·3	+7·8	15·64	79·7	17 42 5	8 59 50	80·7	15·66	80·3	G. S. J.	·64484	8·1197	8·1176	+·0021	8·1186		
„ „	15 21	2·8240	0·44	82·0	„	15·20	81·6	17 41 55	8 59 42	81·0	15·55	81·4	G. S. J.	·64478	8·1186	8·1169	+·0017	8·1177	8·1145	3·7414
„ 21	12 6	2·8234	0·43	84·7	+9·0	15·02	82·8	17 42 12	8 59 55	85·0	14·83	83·4	V. G. G.	·64530	8·1180	8·1156	+·0024	8·1168		
„ „	15 20	2·8245	0·43	83·7	„	14·16	83·7	17 42 27	9 0 2	85·3	14·53	83·9	V. G. G.	·64533	8·1128	8·1105	+·0023	8·1116		
„ 28	12 4	2·8270	0·41	86·1	+9·6	13·62	83·7	17 43 10	9 0 22	84·0	13·49	84·1	G. S. J.	·64479	8·1062	8·1042	+·0020	8·1052		
„ „	15 13	2·8271	0·39	86·1	„	13·45	85·0	17 42 50	9 0 10	84·0	13·50	84·6	G. S. J.	·64470	8·1072	8·1053	+·0019	8·1062		

Aug.	4	12	9	2·8233	0·36	86·9	+8·3	15·05	84·8	17	40	25	8	59	5	86·7	14·91	85·4	V. G. G.	·64510	8·1251	8·1223	+·0028	8·1237		
"	"	15	19	2·8245	0·35	86·6	"	14·40	85·9	17	40	37	8	59	12	87·6	14·55	85·9	V. G. G.	·64506	8·1199	8·1171	+·0028	8·1185		
"	11	11	58	2·8249	0·37	87·4	+7·5	14·72	84·0	17	40	32	8	59	7	85·1	14·64	84·8	G. S. J.	·64473	8·1219	8·1195	+·0024	8·1207		
"	"	15	14	2·8256	0·37	87·3	"	14·31	86·0	17	40	47	8	59	12	85·0	14·51	85·6	G. S. J.	·64467	8·1190	8·1169	+·0021	8·1179		
"	18	12	8	2·8254	0·41	85·4	+8·2	14·54	83·9	17	40	45	8	59	10	85·0	14·61	84·1	P.	·64455	8·1180	8·1160	+·0020	8·1170	8·1179	3·7430
"	"	15	13	2·8261	0·41	83·1	"	14·08	83·1	17	40	52	8	59	17	84·7	14·22	83·8	P.	·64433	8·1139	8·1115	+·0024	8·1127		
"	25	11	55	2·8248	0·37	84·1	+8·0	14·89	83·0	17	41	17	8	59	32	82·7	14·95	83·0	G. S. J.	·64460	8·1190	8·1161	+·0029	8·1175		
"	"	15	11	2·8251	0·37	84·2	"	14·55	83·7	17	41	37	8	59	40	82·9	14·74	83·6	G. S. J.	·64472	8·1169	8·1143	+·0026	8·1156		
Sept.	2	12	11	2·8243	0·38	80·4	+7·7	15·47	79·8	17	41	25	8	59	30	80·8	15·43	79·9	P.	·64429	8·1184	8·1163	+·0021	8·1173		
"	"	15	2	2·8249	0·37	81·2	"	15·12	79·8	17	41	37	8	59	37	81·2	15·19	79·9	P.	·64436	8·1163	8·1141	+·0022	8·1152		
"	8	12	27	2·8252	0·38	86·8	+7·8	14·84	84·9	17	40	25	8	59	2	84·6	14·67	85·1	G. S. J.	·64445	8·1216	8·1191	+·0025	8·1203		
"	"	15	0	2·8264	0·34	87·0	"	14·12	86·0	17	40	42	8	59	10	84·7	14·39	85·8	G. S. J.	·64448	8·1171	8·1148	+·0023	8·1159		
"	15	12	5	2·8256	0·35	88·1	+8·2	14·39	85·1	17	40	52	8	59	15	87·4	14·20	85·4	V. G. G.	·64479	8·1173	8·1150	+·0023	8·1161		
"	"	15	14	2·8262	0·34	87·3	"	13·81	86·8	17	41	0	8	59	20	88·4	14·02	86·3	V. G. G.	·64485	8·1135	8·1111	+·0024	8·1123	8·1150	3·7417
"	22	12	3	2·8262	0·36	86·2	+7·6	14·32	84·0	17	41	45	8	59	40	84·4	14·29	84·4	G. S. J.	·64464	8·1133	8·1113	+·0020	8·1123		
"	"	15	16	2·8262	0·35	86·5	"	14·12	85·8	17	41	20	8	59	32	85·0	14·22	85·3	G. S. J.	·64461	8·1147	8·1120	+·0027	8·1133		
"	29	12	3	2·8248	0·36	86·6	+7·3	14·99	85·2	17	41	10	8	59	25	87·0	14·94	85·7	P.	·64502	8·1175	8·1150	+·0025	8·1162		
"	"	15	18	2·8262	0·36	86·3	"	14·16	86·1	17	41	37	8	59	37	86·4	14·54	86·1	P.	·64494	8·1120	8·1098	+·0022	8·1109		
Oct.	6	12	8	2·8248	0·36	85·5	+7·5	15·01	83·9	17	41	2	8	59	17	83·7	14·65	84·6	G. S. J.	·64450	8·1199	8·1180	+·0019	8·1189		
"	"	15	22	2·8274	0·38	85·5	"	13·49	85·0	17	42	5	8	59	52	83·7	13·81	85·1	G. S. J.	·64451	8·1087	8·1062	+·0025	8·1074		
"	14	12	7	2·8274	0·37	88·6	+8·7	13·94	87·2	17	41	35	8	59	42	89·0	13·85	87·9	P.	·64485	8·1085	8·1055	+·0030	8·1070		
"	"	15	5	2·8282	0·37	87·2	"	13·30	88·3	17	42	0	8	59	52	89·4	13·39	88·2	P.	·64475	8·1031	8·1005	+·0026	8·1018		
"	20	12	1	2·8242	0·36	85·8	+8·4	15·12	83·8	17	40	22	8	58	57	84·7	15·01	83·8	G. S. J.	·64460	8·1236	8·1218	+·0018	8·1227	8·1137	3·7411
"	"	15	11	2·8255	0·37	84·8	"	14·63	83·9	17	40	35	8	59	2	84·7	14·70	84·2	G. S. J.	·64441	8·1182	8·1165	+·0017	8·1173		
"	27	12	10	2·8249	0·36	89·1	+8·5	14·63	86·6	17	40	27	8	59	0	88·7	14·40	87·1	V. G. G.	·64499	8·1206	8·1188	+·0018	8·1197		
"	"	15	10	2·8256	0·36	87·2	"	13·97	86·9	17	40	55	8	59	10	88·6	14·03	87·3	V. G. G.	·64494	8·1154	8·1139	+·0015	8·1146		
Nov.	3	12	6	2·8269	0·38	91·2	+8·7	14·13	89·0	17	39	27	8	58	22	89·0	13·92	89·7	G. S. J.	·64438	8·1201	8·1191	+·0010	8·1196		
"	"	15	22	2·8295	0·42	90·4	"	12·71	90·2	17	40	42	8	59	2	90·0	12·84	90·5	G. S. J.	·64432	8·1062	8·1049	+·0013	8·1055		
"	10	12	0	2·8264	0·42	86·1	+9·3	15·14	83·8	17	40	52	8	59	7	86·5	14·70	84·4	V. G. G.	·64427	8·1141	8·1128	+·0013	8·1134		
"	"	15	14	2·8278	0·42	85·0	"	14·13	85·5	17	41	12	8	59	17	87·9	14·29	85·9	V. G. G.	·64436	8·1066	8·1053	+·0013	8·1059		
"	17	12	5	2·8263	0·41	86·1	+7·8	15·30	84·0	17	40	52	8	59	5	86·4	15·09	84·4	P.	·64436	8·1143	8·1133	+·0010	8·1138	8·1106	3·7396
"	"	15	2	2·8270	0·42	84·8	"	14·68	85·0	17	41	20	8	59	17	86·5	14·78	85·0	P.	·64436	8·1092	8·1085	+·0007	8·1088		
"	24	12	7	2·8274	0·41	86·6	+9·4	14·78	83·5	17	41	22	8	59	17	83·8	14·55	84·6	V. G. G.	·64414	8·1122	8·1117	+·0005	8·1119		
"	"	15	11	2·8285	0·41	84·8	"	14·11	85·0	17	41	47	8	59	27	84·0	14·25	85·1	V. G. G.	·64399	8·1059	8·1055	+·0004	8·1057		
Dec.	1	12	10	2·8281	0·47	87·0	+9·4	14·42	84·0	17	41	30	8	59	20	85·0	14·28	84·6	P.	·64414	8·1090	8·1085	+·0005	8·1087		
"	"	15	7	2·8289	0·48	85·1	"	13·96	85·9	17	41	55	8	59	30	85·2	14·08	85·8	P.	·64402	8·1033	8·1031	+·0002	8·1032		
"	8	12	20	2·8272	0·47	83·5	+10·5	14·94	81·2	17	42	50	9	0	0	83·2	14·55	81·9	V. G. G.	·64424	8·1053	8·1048	+·0005	8·1050		
"	"	15	0	2·8294	0·49	84·2	"	14·36	83·8	17	42	37	8	59	52	84·8	14·53	83·3	V. G. G.	·64404	8·0992	8·0986	+·0006	8·0989		
"	15	12	11	2·8263	0·49	86·8	+8·9	15·16	83·8	17	41	57	8	59	37	85·0	14·96	84·4	P.	·64464	8·1122	8·1111	+·0011	8·1116		
"	"	15	2	2·8275	0·49	83·6	"	14·48	84·7	17	42	17	8	59	45	84·3	14·79	84·5	P.	·64439	8·1055	8·1048	+·0007	8·1051	8·1070	3·7380
"	22	11	53	2·8270	0·50	83·0	+9·4	15·55	80·8	17	40	30	8	58	52	82·9	15·59	81·9	V. G. G.	·64378	8·1141	8·1133	+·0008	8·1137		
"	"	14	30	2·8281	0·49	83·3	"	14·78	83·3	17	41	5	8	59	5	82·7	15·12	83·3	V. G. G.	·64377	8·1094	8·1092	+·0002	8·1093		
"	29	12	18	2·8272	0·51	83·0	+9·2	15·19	80·1	17	41	10	8	59	10	82·9	15·41	80·4	P.	·64396	8·1111	8·1105	+·0006	8·1108		
"	"	15	8	2·8291	0·51	82·1	"	14·50	81·3	17	41	32	8	59	17	83·0	14·81	81·0	P.	·64355	8·1035	8·1035	·0000	8·1035		

The mean value of the Horizontal Force for the year 1886 = 8·1147 | 3·7415

Absolute Magnetical Observations.—Table II.

Observations of Absolute Declination.

1886.

1886. Date.	Bombay Civil Time.	Mean Readings. Collimator Magnet. Scale apparently Erect.	Inverted.	Horizontal Circle with Telescope pointed to. Scale of Collimator Magnet.	Tárdeo Chimney.	Torsion. Mean.	Effect of 90°.	Observer.	Corresponding Reading of large Declination Magnetometer.	Absolute Easterly Declination corrected for Torsion.	Monthly Mean. Corresponding Reading of large Declination Magnetometer.	Absolute Easterly Declination.
1	2	3	4	5	6	7	8	9	10	11	12	13
	h. m.	Sc. div.	Sc. div.	° ′ ″	° ′ ″	°	Sc. div.		Sc. div.	° ′ ″	Sc. div.	° ′ ″
JAN. 7	11 48	+1·52	+1·62	17 20 40	196 53 15	10W	0·75	P.	36·55	0 53 55		
,, 14	11 17	+1·51	+1·60	17 23 20	196 54 30	0		G. S. J.	36·74	0 55 10	36·58	0 54 0
,, 21	11 21	+1·54	+1·61	17 21 40	196 54 20	0		V. G. G.	36·53	0 53 42		
,, 28	11 14	+1·52	+1·57	17 20 10	196 53 20	0		G. S. J.	36·49	0 53 13		
FEB. 4	11 19	+1·52	+1·64	17 21 40	196 53 25	0		V. G. G.	36·71	0 54 33		
,, 11	11 26	+1·60	+1·44	17 22 0	196 53 40	0		G. S. J.	36·78	0 54 57	36·64	0 54 5
,, 18	11 27	+1·51	+1·62	17 21 20	196 53 45	0		V. G. G.	36·60	0 53 54		
,, 25	11 21	+1·50	+1·59	17 19 20	196 52 45	0		G. S. J.	36·47	0 52 55		
MAR. 5	11 24	+1·54	+1·61	17 21 50	196 52 55	0		V. G. G.	36·82	0 55 17		
,, 11	11 21	+1·50	+1·56	17 21 20	196 54 20	0		G. S. J.	36·51	0 53 22	36·62	0 53 57
,, 18	11 32	+1·51	+1·66	17 20 0	196 54 0	0		V. G. G.	36·36	0 52 16		
,, 25	11 28	+1·52	+1·61	17 22 0	196 53 25	0		G. S. J.	36·79	0 54 55		
APRIL 1	11 31	+1·52	+1·56	17 21 30	196 53 35	0		V. G. G.	36·69	0 54 18		
,, 8	11 18	+1·44	+1·67	17 19 20	196 53 40	0		G. S. G.	36·30	0 51 51		
,, 15	11 22	+1·54	+1·61	17 19 50	196 53 40	10E	0·56	V. G. G.	36·39	0 52 23	36·40	0 52 25
,, 22	11 39	+1·52	+1·61	17 19 0	196 53 30	0		G. S. J.	36·31	0 51 50		
,, 29	11 22	+1·59	+1·51	17 18 50	196 53 40	0		V. G. G.	36·29	0 51 42		
MAY 6	11 11	+1·55	+1·54	17 18 20	196 53 5	0		G. S. J.	36·29	0 51 41		
,, 13	11 24	+1·54	+1·59	17 17 50	196 53 25	0		V. G. G.	36·15	0 50 48		
,, 20	11 18	+1·50	+1·66	17 18 20	196 53 20	10E	0·57	G. S. J.	36·20	0 51 6	36·19	0 51 6
,, 27	11 31	+1·50	+1·66	17 18 20	196 53 45	0		P.	36·12	0 50 50		
JUNE 3	11 24	+1·52	+1·62	17 19 10	196 53 0	0		G. S. J.	36·35	0 52 29		
,, 10	11 18	+1·49	+1·72	17 20 40	196 53 30	0		P.	36·47	0 53 21		
,, 17	11 17	+1·49	+1·69	17 18 50	196 53 20	0		G. S. J.	36·22	0 51 42	36·31	0 52 20
,, 24	11 27	+1·54	+1·62	17 19 10	196 53 40	0		P.	36·22	0 51 50		
JULY 1	11 24	+1·56	+1·56	17 19 20	196 53 10	0		G. S. J.	36·33	0 52 36		
,, 8	11 20	+1·52	+1·66	17 20 10	196 53 0	0		V. G. G.	36·45	0 53 26		
,, 15	11 26	+1·52	+1·57	17 18 50	196 52 40	0		G. S. J.	36·31	0 52 33	36·36	0 52 49
,, 22	11 25	+1·57	+1·54	17 18 45	196 52 40	0		V. G. G.	36·31	0 52 32		
,, 29	11 24	+1·52	+1·57	17 18 40	196 52 5	0		G. S. J.	36·38	0 52 58		
AUG. 5	11 23	+1·52	+1·64	17 17 30	196 52 5	0		V. G. G.	36·21	0 51 43		
,, 12	11 21	+1·59	+1·49	17 15 50	196 51 5	0		G. S. J.	36·13	0 51 18	36·14	0 51 25
,, 19	11 28	+1·46	+1·76	17 17 0	196 52 0	0		P.	36·09	0 51 5		
,, 26	11 17	+1·50	+1·65	17 18 0	196 52 40	0		G. S. J.	36·15	0 51 36		
SEPT. 3	11 26	+1·57	+1·59	17 16 10	196 52 0	0		P.	36·02	0 50 35		
,, 9	11 15	+1·46	+1·70	17 16 40	196 51 45	0		G. S. J.	36·09	0 51 4		
,, 16	11 24	+1·54	+1·56	17 16 50	196 51 40	0		V. G. G.	36·18	0 51 35		
,, 23	11 14	+1·51	+1·62	17 17 40	196 52 10	0		G. S. J.	36·21	0 51 49	36·12	0 51 13
,, 30	11 24	+1·47	+1·74	17 17 0	196 52 5	0		P.	36·12	0 51 3		
OCT. 8	11 18	+1·57	+1·45	17 17 40	196 52 5	0		G. S. J.	36·27	0 52 9		
,, 15	11 32	+1·55	+1·62	17 17 35	196 52 0	0		P.	36·25	0 51 57		
,, 21	11 26	+1·55	+1·56	17 18 10	196 52 40	0		G. S. J.	36·23	0 51 56	36·27	0 52 8
,, 29	11 30	+1·52	+1·61	17 18 30	196 52 20	0		P.	36·34	0 52 30		
NOV. 4	11 24	+1·52	+1·64	17 19 0	196 52 40	0		G. S. J.	36·35	0 52 38		
,, 11	11 19	+1·52	+1·61	17 18 20	196 52 30	0		V. G. G.	36·29	0 52 10		
,, 18	11 15	+1·52	+1·60	17 18 20	196 52 40	0		P.	36·26	0 52 0	36·32	0 52 28
,, 25	11 27	+1·59	+1·54	17 19 10	196 52 35	0		V. G. G.	36·40	0 53 4		
DEC. 2	11 19	+1·57	+1·52	17 18 0	196 52 50	5W	0·55	P.	36·22	0 51 43		
,, 9	11 20	+1·57	+1·52	17 20 0	196 53 10	0		V.G. G.	36·45	0 53 19		
,, 16	11 29	+1·52	+1·62	17 19 20	196 53 20	0		P.	36·31	0 52 19	36·40	0 52 56
,, 23	11 22	+1·54	+1·56	17 20 0	196 53 30	0		V. G. G.	36·41	0 52 55		
,, 30	11 46	+1·52	+1·61	17 21 40	196 53 35	0		V. G. G.	36·63	0 54 25		

The Mean Declination for the year 1886 = ° ′ ″ 0 52 34

Absolute Magnetical Observations.—Table III.

Observations of Inclination, 1886.

Taken with Barrow's Dip Circle, with Microscopes, No. 49 and two 3½ inch Needles Nos. 2 and $\frac{2}{81}$ by John Dover.

1886. Date.	Bombay Civil Time (0 to 24 hours). At commencement.	At conclusion.	Observer.	Needle marked.	End of Needle Dipping. A. Face of Circle. East.	A. Face of Circle. West.	B. Face of Circle. East.	B. Face of Circle. West.	Mean Dip.	Monthly Mean for each Needle.	Monthly Mean.
	h. m.	h. m.			° ′	° ′	° ′	° ′	° ′		° ′
Jan. 1	15 5	16 19	C	$\frac{2}{81}$	20 7·6	19 15·9	20 23·9	19 26·2	19 48·4	No. $\frac{2}{81}$ ° ′	
,, 5	11 6	12 28	P.	$\frac{2}{81}$	20 5·1	19 19·5	20 21·7	19 26·6	19 48·2		
,, 8	15 5	16 24	P.	2	20 35·7	19 13·5	20 6·0	19 1·9	19 44·3	19 47·8	
,, 11	11 6	12 36	G.S.J.	2	20 36·4	19 16·4	20 2·7	18 59·6	19 43·8		
,, 15	15 2	16 24	G.S.J.	$\frac{2}{81}$	20 2·6	19 21·4	20 21·4	19 25·7	19 47·8		19 46·1
,, 19	11 10	12 33	V.G.G.	$\frac{2}{81}$	20 6·7	19 17·2	20 29·2	19 15·1	19 47·0	No. 2 ° ′	
,, 22	15 14	16 35	V.G.G.	2	20 29·2	19 15·4	20 9·0	19 3·0	19 44·1		
,, 26	11 20	12 47	G.S.J.	2	20 28·9	19 15·7	20 8·6	19 2·5	19 43·9	19 44·0	
,, 29	15 5	16 33	G.S.J.	$\frac{2}{81}$	20 5·6	19 17·7	20 21·1	19 25·2	19 47·4		
Feb. 2	11 4	12 35	V.G.G.	$\frac{2}{81}$	20 4·1	19 20·5	20 16·5	19 27·9	19 47·2	No. $\frac{2}{81}$ ° ′	
,, 5	15 6	16 35	V.G.G.	2	20 27·6	19 21·5	20 7·2	19 1·6	19 44·5		
,, 9	11 9	12 41	G.S.J.	2	20 23·5	19 21·6	20 6·1	18 59·4	19 42·6	19 48·0	
,, 12	15 20	16 45	G.S.J	$\frac{2}{81}$	20 1·5	19 22·6	20 19·0	19 30·4	19 48·4		19 45·9
,, 16	11 10	12 40	V.G.G.	$\frac{2}{81}$	20 5·6	19 19·1	20 18·4	19 30·4	19 48·4	No. 2 ° ′	
,, 20	15 11	16 35	V.G.G.	2	20 23·1	19 27·9	20 6·9	18 57·5	19 43·8		
,, 23	11 3	12 33	G.S.J.	2	20 20·0	19 19·5	20 12·2	19 6·2	19 44·5	19 43·8	
,, 26	15 8	16 31	G.S.J.	$\frac{2}{81}$	19 58·9	19 20·4	20 25·7	19 27·4	19 48·1		
Mar. 2	11 3	12 33	V.G.G.	$\frac{2}{81}$	20 10·9	19 8·7	20 3·0	19 50·0	19 48·1	No. $\frac{2}{81}$ ° ′	
,, 5	15 4	16 35	V.G.G.	2	20 25·6	19 14·1	20 14·7	19 5·1	19 44·9		
,, 9	11 9	12 33	G.S.J.	2	20 18·5	19 21·9	19 59·0	19 13·6	19 43·2	19 47·9	
,, 12	15 1	16 25	G.S.J.	$\frac{2}{81}$	20 12·0	19 11·7	20 3·0	19 46·2	19 48·2		
,, 16	11 6	12 30	V.G.G.	$\frac{2}{81}$	19 56·1	19 28·9	20 2·6	19 43·5	19 47·8		19 46·1
,, 18	15 10	16 33	V.G.G.	2	20 9·1	19 20·5	20 15·5	19 10·2	19 43·8		
,, 23	11 15	12 42	G.S.J.	2	20 6·5	19 14·7	20 5·5	19 26·0	19 43·2	No. 2 ° ′	
,, 26	15 16	16 36	G.S.J.	$\frac{2}{81}$	19 49·1	19 27·7	20 12·2	19 41·5	19 47·6	19 43·8	
,, 30	11 14	12 37	V.G.G.	$\frac{2}{81}$	19 57·1	19 25·7	20 6·9	19 41·6	19 47·8		
April 2	15 10	16 32	V.G.G.	2	20 4·4	19 18·5	20 3·6	19 25·1	19 42·9	No. $\frac{2}{81}$ ° ′	
,, 6	11 8	12 33	G.S.J.	2	20 1·9	19 19·4	19 59·7	19 30·4	19 42·8		
,, 9	15 6	16 31	G.S.J.	$\frac{2}{81}$	19 49·4	19 26·4	20 16·4	19 38·5	19 47·7	19 47·7	
,, 13	11 17	12 32	V.G.G.	$\frac{2}{81}$	19 44·6	19 30·4	20 22·0	19 33·7	19 47·7		
,, 16	15 5	16 33	V.G.G.	2	19 55·0	19 24·6	20 3·5	19 27·4	19 42·6		19 45·1
,, 20	11 6	12 30	G.S.J.	2	19 56·1	19 22·7	19 55·5	19 40·6	19 43·7	No. 2 ° ′	
,, 23	15 3	16 17	C.	$\frac{2}{81}$	19 46·3	19 26·6	20 26·3	19 33·0	19 48·0		
,, 27	11 5	12 24	V.G.G.	$\frac{2}{81}$	19 40·5	19 27·3	20 25·4	19 36·5	19 47·4	19 42·9	
,, 30	15 4	16 30	V.G.G.	2	19 54·0	19 23·5	20 2·2	19 31·1	19 42·7		

1886. Date.	Bombay Civil Time (0 to 24 hours). At commencement.	At conclusion.	Observer.	Needle marked.	End of Needle Dipping. A. Face of Circle. East.	A. Face of Circle. West.	B. Face of Circle. East.	B. Face of Circle. West.	Mean Dip.	Monthly Mean for each Needle.	Monthly Mean.
	h. m.	h. m.			° ′	° ′	° ′	° ′	° ′		° ′
MAY 4	11 10	12 32	G.S.J.	2	20 1·9	19 19·1	19 56·7	19 38·7	19 44·1		
,, 7	15 9	16 31	G.S.J.	2/81	19 43·1	19 22·0	20 26·9	19 40·1	19 48·0	No. 2/81 ° ′	
,, 11	11 3	12 30	V.G.G.	2/81	19 46·5	19 27·4	20 24·2	19 33·1	19 47·8	19 47·5	
,, 14	15 3	16 33	V.G.G.	2	20 3·4	19 15·6	19 51·9	19 42·1	19 43·2		19 45·6
,, 18	11 11	12 38	G.S.J.	2	20 11·8	19 22·2	19 50·0	19 32·1	19 44·0		
,, 21	15 13	16 33	G.S.J.	2/81	19 41·8	19 34·2	20 22·0	19 32·1	19 47·5	No. 2 ° ′	
,, 25	10 55	12 12	P.	2/81	19 51·1	19 23·2	20 25·2	19 28·2	19 46·9		
,, 28	15 2	16 22	P.	2	20 13·9	19 18·4	19 44·0	19 37·4	19 43·4	19 43·7	
JUNE 1	11 13	12 36	G.S.J.	2	20 13·7	19 16·5	19 38·9	19 47·4	19 44·1		
,, 4	14 57	16 22	G.S.J.	2/81	19 45·1	19 19·6	20 30·3	19 35·6	19 47·6	No. 2/81 ° ′	
,, 8	11 5	12 27	P.	2/81	19 51·7	19 14·9	20 28·8	19 35·7	19 47·8	19 47·8	
,, 11	15 2	16 25	P.	2	20 18·9	19 20·4	19 43·5	19 34·0	19 44·2		
,, 15	11 6	12 28	G.S.J.	2	20 24·0	19 16·0	19 35·5	19 40·0	19 43·9		19 45·6
,, 18	15 15	16 40	G.S.J.	2/81	19 48·2	19 13·6	20 24·9	19 44·2	19 47·7		
,, 22	11 5	12 26	P.	2/81	19 50·2	19 9·6	20 35·1	19 38·2	19 48·3	No. 2 ° ′	
,, 25	15 11	16 28	P.	2	20 21·7	19 15·0	19 46·4	19 33·5	19 44·1		
,, 29	11 8	12 38	G.S.J.	2	20 23·9	19 12·4	19 39·6	19 36·2	19 43·0	19 43·9	
JULY 2	14 55	16 18	G.S.J.	2/81	19 42·2	19 12·7	20 34·1	19 47·7	19 49·2		
,, 6	11 10	12 35	V.G.G.	2/81	19 44·5	19 10·7	20 34·6	19 45·0	19 48·7	No. 2/81 ° ′	
,, 9	15 4	16 32	V.G.G.	2	20 22·9	19 10·5	19 41·0	19 39·1	19 43·4		
,, 13	11 14	12 42	G.S.J.	2	20 22·6	19 12·0	19 36·7	19 43·0	19 43·6	19 48·8	
,, 16	15 7	16 33	G.S.J.	2/81	19 40·0	19 13·7	20 38·0	19 45·0	19 49·2		19 46·3
,, 20	11 15	12 36	V.G.G.	2/81	19 41·7	19 15·5	20 38·4	19 40·0	19 48·9		
,, 23	15 10	16 30	V.G.G.	2	20 25·4	19 8·6	19 37·6	19 41·4	19 43·2		
,, 27	11 14	12 41	G.S.J.	2	20 21·2	19 7·2	19 36·1	19 46·1	19 42·6	No. 2 ° ′	
,, 30	14 53	16 22	G.S.J.	2/81	19 46·7	19 19·2	20 30·0	19 37·0	19 48·2	19 43·2	
AUG. 3	11 10	12 35	V.G.G.	2/81	19 51·6	19 18·2	20 25·1	19 37·9	19 48·2		
,, 6	15 7	16 31	V.G.G.	2	20 23·2	19 7·6	19 36·1	19 43·1	19 42·5	No. 2/81 ° ′	
,, 10	11 13	12 36	G.S.J.	2	20 16·6	19 10·6	19 41·7	19 42·6	19 42·9		
,, 13	15 7	16 35	G.S.J.	2/81	19 52·1	19 16·2	20 17·5	19 47·7	19 48·4	19 48·2	
,, 17	11 5	12 31	P.	2/81	19 55·0	19 12·1	20 23·0	19 43·7	19 48·4		19 45·8
,, 20	15 2	16 26	P.	2	20 19·2	19 10·1	19 49·2	19 35·0	19 43·4		
,, 24	11 6	12 32	G.S.J.	2	20 16·9	19 13·4	19 46·4	19 32·7	19 42·3		
,, 27	15 1	16 22	G.S.J.	2/81	19 46·0	19 10·5	20 19·4	19 54·2	19 47·5	No. 2 ° ′	
,, 31	11 4	12 27	P.	2/81	19 52·2	19 13·4	20 17·7	19 51·0	19 48·6	19 42·8	

1886. Date.	Bombay Civil Time (0 to 24 hours). At commencement.	At conclusion.	Observer.	Needle marked.	End of Needle Dipping. A. Face of Circle. East.	A. Face of Circle. West.	B. Face of Circle. East.	B. Face of Circle. West.	Mean Dip.	Monthly Mean for each Needle.	Monthly Mean.
	h. m.	h. m.			° ′	° ′	° ′	° ′	° ′		° ′
SEPT. 3	15 6	16 31	P.	2	20 19·1	19 12·6	19 52·0	19 32·0	19 43·9	No. $\frac{2}{81}$	
„ 7	11 10	12 34	G.S.J.	2	20 20·7	19 11·0	19 44·6	19 37·0	19 43·3	° ′ 19 48·2	
„ 10	15 16	16 42	G.S.J.	$\frac{2}{81}$	19 52·0	19 15·4	20 6·0	19 59·9	19 48·3		
„ 14	11 10	12 30	V.G.G.	$\frac{2}{81}$	19 55·0	19 16·1	20 12·4	19 49·0	19 48·1		19 45·9
„ 17	15 10	16 34	V.G.G.	2	20 20·9	19 11·6	19 48·4	19 34·0	19 43·7		
„ 21	11 0	12 30	G.S.J	2	20 17·2	19 12·0	19 52·4	19 33·1	19 43·7	No. 2	
„ 24	15 0	16 22	G.S.J.	$\frac{2}{81}$	19 55·4	19 19·6	20 3·6	19 55·0	19 48·4	° ′ 19 43·6	
„ 27	11 20	12 42	P.	$\frac{2}{81}$	19 56·6	19 19·4	20 3·6	19 52·5	19 48·0		
OCT. 1	15 2	16 22	P.	2	20 21·7	19 7·9	19 55·9	19 32·7	19 44·5	No. $\frac{2}{81}$	
„ 5	11 15	12 43	G.S.J.	2	20 27·7	19 6·6	19 51·0	19 31·1	19 44·1	° ′ 19 48·4	
„ 8	15 12	16 38	G.S.J.	$\frac{2}{81}$	19 59·4	19 18·5	20 2·5	19 54·5	19 48·7		
„ 12	11 6	12 31	P.	$\frac{2}{81}$	19 59·7	19 18·4	20 2·5	19 50·7	19 47·8		
„ 15	15 2	16 23	P.	2	20 26·9	19 9·5	19 49·9	19 28·4	19 43·7		19 45·9
„ 19	11 10	12 33	G.S.J.	2	20 31·2	19 10·2	19 45·6	19 26·5	19 43·4		
„ 22	15 8	16 29	G.S.J.	$\frac{2}{81}$	19 56·2	19 20·0	20 5·7	19 54·2	19 49·0	No. 2 ° ′ 19 43·9	
„ 25	11 5	12 34	P.	$\frac{2}{81}$	19 59·2	19 17·6	20 7·7	19 47·7	19 48·0		
„ 29	15 8	16 35	P.	2	20 28·7	19 9·9	19 50·9	19 25·6	19 43·8		
NOV. 2	11 12	12 37	G.S.J.	2	20 26·7	19 9·0	19 48·9	19 28·9	19 43·4		
„ 5	15 5	16 31	P.	$\frac{2}{81}$	19 59·6	19 17·2	20 6·9	19 51·2	19 48·7	No. $\frac{2}{81}$	
„ 9	11 10	12 35	V.G.G.	$\frac{2}{81}$	19 56·4	19 19·1	20 7·4	19 53·0	19 49·0	° ′ 19 48·2	
„ 12	15 10	16 35	V.G.G.	2	20 29·2	19 11·5	19 47·6	19 25·0	19 43·3		
„ 16	11 5	12 25	P.	2	20 27·5	19 11·0	19 52·1	19 24·5	19 43·8		19 45·7
„ 19	15 3	16 24	P.	$\frac{2}{81}$	20 0·1	19 16·7	19 57·0	19 56·0	19 47·4		
„ 23	11 15	12 40	V.G.G.	$\frac{2}{81}$	19 53·4	19 18·4	20 2·5	19 57·4	19 47·9	No. 2 ° ′ 19 43·7	
„ 26	15 10	16 34	V.G.G.	2	20 27·4	19 17·5	19 50·7	19 21·2	19 44·2		
„ 30	11 0	12 24	P.	2	20 21·1	19 17·7	19 51·1	19 24·7	19 43·6		
DEC. 2	15 6	16 27	P.	$\frac{2}{81}$	20 1·1	19 19·7	19 59·0	19 53·1	19 48·2		
„ 7	11 10	12 35	V.G.G.	$\frac{2}{81}$	19 51·6	19 26·7	20 2·2	19 54·6	19 48·8	No. $\frac{2}{81}$	
„ 10	15 8	16 32	V.G.G.	2	20 22·5	19 24·4	19 46·2	19 22·9	19 44·0	° ′ 19 48·5	
„ 14	11 0	12 22	P.	2	20 18·2	19 24·2	19 44·9	19 28·4	19 43·9		
„ 17	15 7	16 26	P.	$\frac{2}{81}$	19 52·6	19 27·2	19 56·2	19 57·4	19 48·3		19 46·4
„ 21	11 7	12 35	V.G.G.	$\frac{2}{81}$	19 47·4	19 35·9	19 56·0	19 56·1	19 48·9		
„ 24	15 5	16 20	C.	2	20 22·9	19 21·1	19 42·1	19 29·2	19 43·8	No. 2	
„ 28	11 12	12 30	V.G.G.	2	20 20·5	19 24·2	19 43·4	19 27·0	19 43·8	° ′ 19 43·9	
„ 31	15 5	16 23	P.	$\frac{2}{81}$	19 51·4	19 27·1	19 58·2	19 56·0	19 48·2		

The Mean Dip for the year ... { With Needle No. $\frac{2}{81}$ = 19 48·1 ° ′ / With Needle No. 2 = 19 43·6

The Mean Dip for the year 1886 = 19° 45′·9

BOMBAY

MAGNETICAL AND METEOROLOGICAL OBSERVATIONS,

1886.

Appendices I to VI,

Being extensions of the Magnetic Investigations contained in the Appendices to the "Bombay Magnetical and Meteorological Observations, 1879-82."

I.—On the Luni-solar variations of magnetic declination and horizontal force at Bombay, and of declination at Trevandrum.

II.—Luni-solar variation of magnetic declination at Batavia, and references to later extensions of the investigations of the preceding paper.

III.—On the influence of temperature upon the Bifilar Magnetometer.

IV.—Effect of heating the Magnetograph Room on the Scale-coefficient of the Vertical Force Magnetograph.

V.—Temperature-coefficient of the Vertical Force Magnetograph.

VI.—Temperature-coefficient of the Horizontal Force Magnetograph.

By

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ERRATA IN APPENDICES.

The letters A_1, B_1, A_2, B_2, in the headings of Tables 19 and 20, pages 26 and 27, and in the first and second lines following Table 20, should be in Egyptian type.

In line 10 of page 36 *for* Columu 2 *read* Columns 2 and 9.

On page 42 after word Postscript and date *insert* 29 as number of paragraph.

In line 54 of page 46 *for* ful *read* full.

In the Appendices to the Bombay Magnetical and Meteorological Observations, 1879-82, and in all the Appendices to this volume, except the first and second, magnetic forces are expressed in m.m—m.g.—s units of force: in Appendices I and II to this volume they are expressed in C.G.S. units.

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APPENDIX I.

On the Luni-solar Variations of Magnetic Declination and Horizontal Force at Bombay, and of Declination at Trevandrum.

[Extracted from the Philosophical Transactions of the Royal Society. Vol. 178 (1887), A. pp. 1—43.]

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PHILOSOPHICAL TRANSACTIONS.

I. *On the Luni-Solar Variations of Magnetic Declination and Horizontal Force at Bombay, and of Declination at Trevandrum.*

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Received March 24,—Read April 1, 1886.

[PLATES 1–5.]

IN the early attempts to investigate the influence of the moon upon terrestrial magnetism, the observations dealt with extended over periods so limited that little was possible beyond determining the average character of the lunar diurnal variation. This was mainly because magnetic disturbance tends—and especially in extra-tropical regions—to mask the minute variations that depend upon the moon. The series of observations made at the Colába Observatory, Bombay, and discussed in the present paper, extending over twenty-five years in the case of the declination and over twenty-six and a half years in the case of the horizontal force, possesses therefore the double advantage of being originally affected by only the relatively small disturbances of a tropical station, and of being lengthy enough to secure an approximate elimination of such disturbance as is involved in it, even by combination of portions only of the whole body of observations.

2. The instruments used at Colába were made by GRUBB, of Dublin, and are like those described in the report (of 1840) of the Committee of Physics of the Royal Society, the magnets being fifteen inches long. An account of them and of their history will be found in the 'Appendices to the Bombay Magnetical and Meteorological Observations, 1879 to 1882,' pages [84] and [138]: and to this account reference may be made for particulars as to the adjustments and determination of scale coefficients of both the declination and horizontal force magnetometers, and as to the determination of the temperature coefficient of the latter instrument. The following extract is, however, given in full, the matter of it being essential to an understanding of the principal object of this paper.

3. *Method of Reduction of the Observations.*—The mode of treatment adopted is that which was introduced by General Sir EDWARD SABINE, and which is described by him in the 'Proceedings of the Royal Society,' vol. 10, pp. 624–626, in the following words:—"The hourly directions of the magnet are entered in monthly

Tables, having the days of the month in successive horizontal lines, and the hours of the day in vertical columns. The 'means' of the entries in each vertical column indicate the mean direction of the magnet at the different hours of the month to which the Table belongs, and have received the name of 'first normals.' On inspecting any such monthly Table, it is at once seen that a considerable portion of the entries in the several columns differ considerably from their respective means or first normals, and must be regarded as 'disturbed observations.' The laws of their relative frequency and amount of disturbance in different years, months, and hours are then sought out by separating for that purpose a sufficient body of the most disturbed observations, computing the amount of departure in each case from the normal of the same month and hour, and arranging the amounts in annual, monthly, and hourly tables. In making these computations, the first normals require to be themselves corrected by the omission in each vertical column of the entries noted as disturbed, and by taking fresh means, representing the normals of each month and hour after this omission, and therefore uninfluenced by the larger disturbances. These new means have received the name of 'final normals,' and may be defined as being the mean directions of the magnet in every month and every hour after the omission from the record of every entry which differed from the mean by a certain amount either in excess or in defect.

"In this process there is nothing indefinite, and nothing arbitrary save the assignment of the particular amount of difference from the normal which shall be held to constitute the measure of a large disturbance, and which, for distinction's sake, we may call 'the separating value.' It must be an amount which will separate a sufficient body of disturbed observations to permit their laws to be satisfactorily ascertained, but in other respects its precise value is of minor significancy; and the limits within which a selection may be made, without materially affecting the results, are usually by no means narrow, for it has been found experimentally on several occasions that the ratios by which the periodical variations of disturbance in different years, months, and hours are characterised and expressed do not undergo any material change by even considerable differences in the amount of the separating value. The separating value must necessarily be larger at some stations than at others, because the absolute magnitude of the disturbance variation itself is very different in different parts of the globe, as well as its comparative magnitude in relation to the more regular solar diurnal variation, but it must be a constant quantity throughout at one and the same station, or it will not truly show the relative proportion of disturbance in different years and different months." The words "directions of the magnet" in the extract must be taken when applied to the Colába declination observations to imply those directions as expressed either by the original scale readings or those readings converted into minutes of easterly declination; and, when applied to the horizontal force observations, to imply the directions as expressed by the original scale readings after reduction to a uniform temperature.

4. The period of the declination observations is from 1846·0 to 1871·0, and that of the horizontal force observations from 1846·5 to 1873·0. With the exception of Sundays and eight or ten complete days in each year, the observations were taken continuously at hourly intervals throughout these periods. The entries in the monthly declination Tables of the years 1846 to 1865 were in minutes of arc, in those of the years 1866 to 1870 in original scale readings, and the "separating value" made

use of was 1'·4 or its equivalent ·204 scale divisions. The separating value adopted for the horizontal force was the equivalent in scale reading of ·000334 of a C.G.S. unit of force.

5. Continuing now the extract—from the monthly Tables already described in it, "all observations having been thrown out which deviated from the 'Final Normal' of each hour by more than the amount of the separating value, new Tables were formed in which each observation was substituted by its excess above the Final Normal of its own hour; or rather, by that excess, *plus* a constant round number. Practically, the Final Normal was diminished by the round number, and the difference being then taken between the number found and each observation in the same hour column, all the differences have the *positive* sign, and thus the inconvenience of dealing with *positive* and *negative* numbers is avoided. On the new Tables the observation at the solar hour of each day which was nearest to the time of the moon's crossing the meridian of Bombay (from East to West) was marked with a figure 0 to indicate that that observation must be placed to the 0th hour of the lunar day in Tables having the lunar hours, from 0 to 23, marked in consecutive order at the top of the several columns. If only twenty-three observations intervened between two marked ones, they were entered in the Table consecutively as forming a complete lunar day; but, as twenty-four observations generally intervened, the two which were in the nearest correspondence to the same lunar hour were combined together, and the mean of the two treated as a single observation." The times of New Moon, First Quarter, Full Moon, and Last Quarter—taken from the Nautical Almanac, and duly corrected for difference of longitude between Greenwich and Bombay, or Göttingen*—were also marked on the margin of the sheet opposite to the several corresponding solar days; for the groups of days, two before and two after these times respectively, the moon was regarded as at the several quarters; and during the intervening days the designations of the moon's phases were one-eighth, three-eighths, five-eighths, and seven-eighths respectively. The entries in the Tables of lunar differences, thus marked, were now distributed, in full lunar days, amongst thirty-two new Tables, called lunar abstracts, of which there was one for each eighth of a cycle of the moon's phases in each quarter of the year. The whole of a lunar day's differences were entered in the lunar abstracts under that variety of phase to which the greater half of the day belonged. Whenever the number of undisturbed observations on a lunar day was less than twelve the whole day's differences were rejected. When all the differences of each category had been entered on their respective lunar Tables, the hourly means were taken on these Tables, and the excess was then found of each of these means above the mean of all the hours; finally, these excesses were converted into force equivalents. The series of hourly excesses thus found may, in a sufficiently extended inquiry, be taken to represent the lunar diurnal variation of declination or horizontal force when the sun and moon have the positions indicated by that particular Table.

6. The following Tables show, for each magnetic element, the converted hourly excesses found on each of the thirty-two lunar abstracts:—†

* Until 1866·0 the records were made at hours of Göttingen Astronomical time; since that date, at hours of Bombay Civil time. All the results tabulated or graphically represented in this paper have reference, however, to the lunar day or the solar astronomical day at the place of observation.

† The calculations having been made also for the summer and winter half-years, and for the full year, their results for these periods are also shown in the Tables.

TABLE I.—Declination at Bombay, showing the Mean Lunar Diurnal Variation at New Moon and One-eighth Phase in each Quarter of the Year.

Phase of Moon.	New moon.							One-eighth.						
Bombay lunar hours.	November to January.	February to April.	May to July.	August to October.	April to September.	October to March.	Year.	November to January.	February to April.	May to July.	August to October.	April to September.	October to March.	Year.
0	+·000016	·000000	−·000012	−·000021	−·000018	+·000010	−·000004	+·000006	−·000002	−·000030	−·000007	−·000019	+·000002	−·000008
1	+·000018	−·000006	−·000018	−·000017	−·000023	+·000012	−·000006	+·000014	−·000002	−·000012	−·000007	−·000007	+·000003	−·000002
2	+·000008	−·000006	−·000008	−·000009	−·000010	+·000002	−·000004	+·000014	+·000004	−·000004	+·000015	+·000001	+·000013	+·000008
3	+·000006	−·000004	−·000002	+·000013	+·000003	+·000003	+·000003	+·000005	+·000006	+·000006	+·000010	+·000003	+·000005	+·000006
4	−·000004	−·000004	−·000002	+·000021	+·000008	−·000004	+·000003	−·000004	+·000005	−·000001	+·000007	+·000003	+·000001	+·000002
5	−·000008	−·000004	+·000017	+·000015	+·000015	−·000006	+·000005	−·000003	−·000002	+·000004	+·000002	+·000002	−·000002	·000000
6	−·000012	−·000007	+·000014	+·000008	+·000010	−·000009	+·000001	−·000004	−·000002	−·000002	·000000	−·000001	−·000004	−·000002
7	−·000011	−·000011	+·000008	+·000004	+·000001	−·000009	−·000003	−·000005	−·000001	·000000	·000000	·000000	−·000004	−·000001
8	−·000006	−·000011	+·000002	+·000006	+·000002	−·000007	−·000002	−·000002	−·000004	·000000	+·000001	·000000	−·000003	−·000001
9	−·000002	−·000005	+·000002	+·000001	+·000002	−·000004	−·000001	−·000003	+·000001	·000000	−·000003	−·000001	−·000002	−·000001
10	−·000001	+·000001	+·000003	+·000002	+·000002	·000000	+·000001	·000000	+·000002	·000000	−·000002	−·000002	+·000003	+·000001
11	+·000004	+·000003	+·000002	+·000001	+·000001	+·000003	+·000003	+·000003	+·000003	−·000001	−·000004	−·000003	+·000005	+·000002
12	+·000004	+·000015	+·000003	+·000002	+·000002	+·000003	+·000005	+·000004	+·000006	+·000004	·000000	−·000001	+·000006	+·000003
13	+·000005	+·000004	−·000001	−·000001	−·000001	+·000005	+·000002	+·000006	+·000001	+·000003	+·000003	+·000003	+·000006	+·000002
14	+·000004	+·000010	·000000	+·000003	+·000001	+·000007	+·000004	+·000006	·000000	−·000002	+·000003	+·000003	+·000006	+·000002
15	+·000005	+·000012	+·000002	·000000	+·000001	+·000009	+·000005	+·000005	−·000001	+·000006	+·000004	+·000003	+·000004	+·000004
16	+·000001	+·000001	+·000005	+·000001	+·000003	+·000002	+·000003	+·000001	−·000004	+·000014	+·000001	+·000010	−·000004	+·000003
17	−·000004	+·000004	+·000010	+·000005	+·000008	−·000001	+·000004	+·000008	+·000002	+·000014	+·000013	+·000015	−·000006	+·000005
18	−·000016	+·000003	+·000012	+·000003	+·000010	−·000010	+·000001	+·000008	−·000009	+·000021	+·000006	+·000014	−·000008	+·000003
19	−·000009	+·000007	+·000012	+·000008	+·000014	−·000005	+·000005	−·000010	+·000005	+·000010	−·000004	+·000006	−·000005	+·000001
20	−·000001	−·000003	−·000008	+·000006	+·000004	−·000006	·000000	−·000006	−·000002	+·000010	−·000003	+·000005	−·000007	·000000
21	−·000008	+·000003	−·000012	−·000012	−·000014	−·000005	−·000007	−·000004	·000000	−·000002	−·000003	−·000002	−·000003	−·000002
22	−·000006	+·000005	−·000009	−·000022	−·000013	−·000002	−·000007	+·000001	−·000005	−·000022	−·000010	−·000017	−·000001	−·000009
23	+·000008	−·000006	−·000018	−·000015	−·000021	+·000003	−·000008	+·000001	−·000013	−·000017	−·000013	−·000021	−·000001	−·000010
Number of lunar days' observations in abstract	289	250	264	249	529	482	1002	198	198	200	210	408	398	806

TABLE II.—Declination at Bombay, showing the Mean Lunar Diurnal Variation at First Quarter and Three-eighths Phase in each Quarter of the Year.

Phase of moon.	First quarter.							Three-eighths.						
Bombay lunar hours.	November to January.	February to April.	May to July.	August to October.	April to September.	October to March.	Year.	November to January.	February to April.	May to July.	August to October.	April to September.	October to March.	Year.
0	+·000018	+·000003	−·000010	−·000002	−·000007	+·000011	+·000002	+·000008	+·000001	−·000001	−·000001	−·000001	+·000004	+·000002
1	+·000012	+·000003	−·000002	·000000	−·000002	+·000007	+·000002	+·000005	·000000	·000000	−·000001	−·000001	+·000003	+·000001
2	+·000006	+·000004	+·000001	+·000001	·000000	+·000004	+·000002	−·000001	−·000002	−·000005	+·000007	−·000001	+·000001	·000000
3	−·000002	−·000002	+·000003	+·000002	+·000002	−·000002	·000000	−·000002	−·000003	−·000004	+·000004	−·000002	·000000	−·000001
4	+·000002	−·000002	·000000	+·000006	−·000001	+·000003	+·000001	−·000002	−·000007	−·000007	+·000002	−·000004	−·000003	−·000003
5	−·000001	−·000004	+·000001	−·000004	−·000001	−·000004	−·000002	−·000010	−·000012	−·000003	−·000005	−·000006	−·000010	−·000008
6	−·000006	+·000001	·000000	−·000003	−·000002	−·000003	−·000002	−·000011	−·000007	−·000005	−·000002	−·000003	−·000009	−·000006
7	−·000002	+·000001	−·000003	−·000005	−·000004	−·000003	−·000003	−·000011	−·000005	−·000003	+·000002	−·000001	−·000007	−·000004
8	−·000005	·000000	−·000005	−·000008	−·000005	−·000005	−·000005	−·000010	+·000003	·000000	+·000003	+·000003	−·000004	−·000001
9	−·000009	−·000002	−·000006	−·000007	−·000004	−·000008	−·000006	−·000007	+·000004	+·000004	−·000004	−·000002	+·000004	+·000003
10	−·000005	+·000001	−·000005	−·000006	−·000005	−·000003	−·000004	−·000002	+·000011	−·000004	−·000012	−·000002	−·000001	−·000002
11	+·000004	+·000011	−·000003	−·000011	−·000008	+·000005	−·000002	+·000001	+·000001	−·000010	−·000013	−·000009	−·000001	−·000005
12	+·000006	+·000011	−·000012	−·000009	−·000009	+·000006	−·000001	+·000011	+·000001	−·000014	−·000007	−·000011	+·000006	−·000003
13	+·000006	+·000001	−·000010	−·000002	−·000009	+·000006	−·000002	+·000022	+·000007	−·000013	−·000007	−·000009	+·000014	+·000002
14	+·000006	−·000001	−·000006	+·000006	·000000	+·000001	+·000001	+·000011	+·000008	−·000009	+·000005	−·000004	+·000011	+·000004
15	+·000008	−·000004	+·000004	+·000014	+·000007	+·000008	+·000005	+·000020	−·000009	+·000001	+·000001	·000000	+·000007	+·000003
16	−·000002	−·000004	+·000020	+·000023	+·000015	+·000002	+·000008	+·000006	−·000003	+·000010	+·000011	+·000009	+·000003	+·000006
17	−·000004	−·000016	+·000013	+·000019	+·000014	−·000009	+·000002	−·000006	+·000011	+·000024	+·000016	+·000020	+·000003	+·000011
18	−·000015	−·000009	+·000013	+·000013	+·000011	−·000011	·000000	−·000002	+·000008	+·000030	+·000008	+·000019	+·000004	+·000012
19	−·000015	−·000004	+·000011	+·000001	+·000008	−·000012	−·000002	+·000019	+·000002	+·000019	+·000007	+·000013	−·000007	+·000003
20	−·000026	−·000005	+·000013	+·000001	+·000009	−·000017	−·000004	−·000014	+·000001	+·000006	−·000005	+·000002	−·000006	+·000002
21	·000000	+·000004	+·000002	−·000006	−·000001	·000000	−·000001	−·000004	−·000001	−·000002	−·000001	−·000001	+·000002	−·000002
22	+·000013	−·000001	−·000010	−·000009	−·000011	+·000006	−·000033	+·000001	−·000007	−·000004	−·000002	−·000004	−·000001	−·000002
23	+·000016	+·000004	−·000009	−·000001	−·000008	+·000012	+·000002	+·000003	−·000002	−·000002	·000000	·000000	·000000	·000000
Number of lunar days' observations in abstract	254	262	264	260	522	518	1040	199	198	213	212	417	405	822

TABLE III.—Declination at Bombay, showing the Mean Lunar Diurnal Variation at Full Moon and Five-eighths Phase in each Quarter of the Year.

Phase of moon.	Full moon.							Five-eighths.						
Bombay lunar hours.	November to January.	February to April.	May to July.	August to October.	April to September.	October to March.	Year.	November to January.	February to April.	May to July.	August to October.	April to September.	October to March.	Year.
0	+ ·000008	·000000	− ·000004	+ ·000002	·000000	+ ·000004	+ ·000002	+ ·000001	+ ·000004	− ·000003	·000000	− ·000001	+ ·000002	+ ·000001
1	+ ·000004	− ·000002	+ ·000002	·000000	+ ·000001	+ ·000001	+ ·000001	+ ·000008	+ ·000009	·000000	+ ·000003	+ ·000003	+ ·000007	+ ·000005
2	+ ·000001	− ·000003	+ ·000003	+ ·000005	+ ·000002	·000000	+ ·000001	+ ·000008	+ ·000002	− ·000004	+ ·000006	+ ·000001	+ ·000004	+ ·000003
3	− ·000006	− ·000007	− ·000001	+ ·000004	·000000	− ·000005	− ·000002	+ ·000010	− ·000007	− ·000001	+ ·000007	+ ·000005	·000000	+ ·000002
4	− ·000007	− ·000006	+ ·000001	+ ·000001	+ ·000001	− ·000006	− ·000003	+ ·000001	− ·000006	+ ·000013	+ ·000005	+ ·000010	− ·000003	+ ·000004
5	− ·000009	− ·000007	+ ·000008	+ ·000005	+ ·000005	− ·000008	·000000	− ·000009	− ·000005	+ ·000015	+ ·000019	+ ·000016	− ·000008	+ ·000006
6	− ·000015	− ·000001	+ ·000006	+ ·000007	+ ·000009	− ·000010	− ·000001	− ·000024	− ·000008	− ·000001	+ ·000009	+ ·000002	− ·000012	− ·000005
7	− ·000011	+ ·000009	+ ·000012	+ ·000009	+ ·000014	− ·000006	+ ·000004	− ·000017	+ ·000004	+ ·000005	+ ·000004	+ ·000004	− ·000007	− ·000001
8	− ·000013	+ ·000004	+ ·000010	+ ·000005	+ ·000007	− ·000007	·000000	− ·000013	·000000	− ·000001	+ ·000001	+ ·000001	− ·000006	− ·000003
9	− ·000017	+ ·000008	+ ·000003	− ·000002	+ ·000001	− ·000005	− ·000003	− ·000015	+ ·000007	− ·000005	− ·000002	− ·000005	− ·000008	− ·000004
10	+ ·000001	+ ·000009	− ·000018	− ·000010	− ·000011	+ ·000001	− ·000005	− ·000010	·000000	− ·000013	− ·000017	− ·000016	− ·000004	− ·000010
11	+ ·000009	+ ·000004	− ·000015	− ·000020	− ·000016	+ ·000005	− ·000005	+ ·000008	− ·000002	− ·000020	− ·000006	− ·000015	+ ·000004	− ·000005
12	+ ·000008	+ ·000001	− ·000020	− ·000015	− ·000015	+ ·000002	− ·000006	+ ·000013	− ·000006	− ·000021	− ·000012	− ·000018	+ ·000005	− ·000006
13	+ ·000012	− ·000005	− ·000015	− ·000014	− ·000014	+ ·000004	− ·000005	+ ·000018	− ·000005	− ·000007	− ·000011	− ·000010	+ ·000007	− ·000001
14	+ ·000020	+ ·000003	− ·000002	− ·000003	·000000	+ ·000007	+ ·000003	+ ·000015	+ ·000003	+ ·000001	+ ·000001	+ ·000002	+ ·000007	+ ·000005
15	+ ·000010	+ ·000002	+ ·000009	+ ·000011	+ ·000008	+ ·000008	+ ·000008	+ ·000003	+ ·000001	+ ·000006	− ·000001	+ ·000004	+ ·000001	+ ·000002
16	− ·000005	+ ·000003	+ ·000009	+ ·000012	+ ·000011	+ ·000001	+ ·000006	·000000	+ ·000006	+ ·000006	+ ·000004	+ ·000006	+ ·000001	+ ·000004
17	− ·000007	·000000	+ ·000009	+ ·000016	+ ·000010	− ·000001	+ ·000005	+ ·000006	·000000	+ ·000006	− ·000003	+ ·000003	+ ·000001	+ ·000003
18	+ ·000001	− ·000005	+ ·000004	+ ·000007	+ ·000001	+ ·000001	+ ·000001	+ ·000002	− ·000001	+ ·000005	·000000	+ ·000004	·000000	+ ·000002
19	+ ·000006	− ·000002	− ·000003	− ·000007	− ·000006	+ ·000003	− ·000001	− ·000001	− ·000010	+ ·000001	+ ·000003	·000000	− ·000004	− ·000002
20	+ ·000006	− ·000002	·000000	− ·000006	− ·000002	+ ·000001	·000000	− ·000004	− ·000002	·000000	+ ·000003	·000000	− ·000001	− ·000001
21	+ ·000003	− ·000001	+ ·000004	+ ·000002	+ ·000001	+ ·000002	+ ·000001	+ ·000002	+ ·000003	+ ·000007	− ·000002	+ ·000004	+ ·000001	+ ·000003
22	+ ·000002	− ·000004	+ ·000001	− ·000003	·000000	− ·000001	− ·000001	− ·000001	+ ·000002	+ ·000805	− ·000001	+ ·000003	·000000	+ ·000001
23	+ ·000004	− ·000001	+ ·000004	+ ·000001	+ ·000004	+ ·000001	+ ·000002	+ ·000003	+ ·000006	+ ·000002	+ ·000001	+ ·000002	+ ·000004	+ ·000003
Number of lunar days' observations in abstract	256	228	254	241	493	486	979	188	192	207	207	406	388	794

TABLE IV.—Declination at Bombay, showing the Mean Lunar Diurnal Variation at Last Quarter and Seven-eighths Phase in each Quarter of the Year.

Phase of moon.	Last quarter.							Seven-eighths.						
Bombay lunar hours.	November to January.	February to April.	May to July.	August to October.	April to September.	October to March.	Year.	November to January.	February to April.	May to July.	August to October.	April to September.	October to March.	Year.
0	+·000010	+·000003	−·000007	−·000010	−·000008	+·000006	−·000001	+·000015	+·000008	−·000016	−·000015	−·000013	+·000010	−·000002
1	+·000009	−·000002	−·000015	−·000009	−·000014	+·000005	−·000004	+·000017	+·000001	−·000016	−·000004	−·000008	+·000008	−·000001
2	+·000011	−·000006	−·000006	−·000007	−·000011	+·000007	−·000002	+·000015	−·000001	−·000003	+·000001	−·000001	+·000008	+·000003
3	+·000014	−·000008	+·000010	−·000001	+·000004	+·000003	+·000004	+·000007	−·000005	+·000007	+·000009	+·000005	+·000005	+·000005
4	·000000	−·000016	+·000019	+·000004	+·000004	−·000005	−·000001	+·000006	−·000005	+·000003	+·000023	+·000007	+·000007	+·000007
5	−·000011	+·000009	·000000	+·000019	+·000008	·000000	+·000004	−·000007	+·000005	+·000001	+·000016	+·000009	−·000001	+·000004
6	−·000018	−·000003	+·000010	+·000015	+·000012	−·000011	+·000001	−·000017	+·000001	+·000010	+·000019	+·000012	−·000005	+·000003
7	−·000025	−·000002	+·000010	+·000032	+·000015	−·000008	+·000003	−·000017	−·000003	+·000007	+·000003	+·000007	−·000012	−·000003
8	−·000029	−·000008	+·000010	+·000005	+·000003	−·000014	−·000005	−·000013	−·000006	+·000001	−·000010	−·000003	−·000010	−·000007
9	−·000014	+·000002	·000000	−·000005	−·000002	−·000007	−·000005	−·000004	−·000006	−·000006	−·000004	−·000005	−·000005	−·000005
10	·000000	−·000001	−·000017	−·000009	−·000013	−·000001	−·000007	−·000001	+·000003	−·000008	−·000005	−·000005	·000000	−·000003
11	+·000010	+·000001	−·000011	−·000009	−·000008	+·000003	−·000003	−·000001	+·000004	−·000002	−·000002	−·000002	+·000001	−·000001
12	+·000011	+·000004	−·000004	+·000001	−·000002	+·000008	+·000003	·000000	+·000007	−·000001	+·000004	+·000002	+·000004	+·000002
13	+·000007	+·000003	+·000001	−·000001	·000000	+·000004	+·000002	+·000002	·000000	+·000002	−·000002	+·000001	+·000001	·000000
14	+·000005	+·000004	+·000001	+·000005	+·000003	+·000004	+·000002	+·000002	+·000008	+·000007	·000000	+·000004	+·000005	+·000004
15	+·000001	−·000001	−·000001	+·000003	−·000002	+·000002	·000000	·000000	+·000002	+·000003	+·000006	+·000005	+·000002	+·000003
16	+·000003	+·000006	+·000001	·000000	+·000001	+·000003	+·000002	−·000004	+·000008	·000000	+·000002	+·000003	·000000	+·000001
17	·000000	+·000006	+·000001	−·000002	·000000	+·000002	+·000001	−·000002	+·000001	+·000001	−·000003	+·000001	−·000002	−·000001
18	−·000003	+·000001	+·000002	−·000001	+·000002	−·000003	−·000001	+·000002	−·000005	+·000003	−·000006	+·000001	−·000003	−·000002
19	·000000	−·000004	+·000002	−·000007	·000000	−·000005	−·000002	+·000002	−·000003	+·000004	−·000005	+·000001	−·000001	−·000001
20	+·000001	−·000001	+·000003	−·000011	+·000003	−·000003	·000000	−·000003	−·000001	+·000012	−·000004	+·000006	−·000004	+·000001
21	+·000006	+·000002	+·000006	−·000006	+·000003	−·000001	+·000001	−·000004	−·000003	+·000005	·000000	+·000001	·000000	·000000
22	+·000010	+·000001	+·000005	−·000006	+·000001	+·000004	+·000002	·000000	−·000001	−·000011	−·000012	−·000011	+·000001	−·000006
23	+·000011	+·000002	−·000003	−·000009	−·000005	+·000005	·000000	+·000005	−·000009	−·000005	−·000022	−·000014	·000000	−·000003
Number of lunar days' observations in abstract	247	255	258	256	515	501	1016	204	198	199	200	402	399	801

TABLE V.—Horizontal Force at Bombay, showing the Mean Lunar Diurnal Variation at New Moon and One-eighth Phase in each Quarter of the Year.

Phase of moon.	New moon.							One-eighth.						
Bombay lunar hours.	November to January.	February to April.	May to July.	August to October.	April to September.	October to March.	Year.	November to January.	February to April.	May to July.	August to October.	April to September.	October to March.	Year.
0	−·000008	·000006	−·000007	−·000009	−·000008	−·000003	−·000006	+·000004	−·000003	+·000013	−·000011	+·000005	−·000005	·000000
1	−·000016	−·000005	−·000009	−·000001	−·000010	−·000006	−·000008	−·000009	−·000007	+·000002	−·000015	−·000004	−·000012	−·000008
2	−·000028	−·000009	−·000009	−·000003	−·000007	−·000017	−·000012	−·000004	·000006	+·000001	−·000025	−·000007	−·000008	−·000008
3	−·000031	−·000017	−·000010	−·000011	−·000013	−·000020	−·000017	−·000015	−·000004	−·000009	−·000019	−·000012	−·000012	−·000012
4	−·000019	−·000021	−·000008	−·000013	−·000012	−·000017	−·000015	+·000004	−·000010	−·000007	−·000008	−·000000	−·000002	−·000006
5	−·000010	−·000009	+·000001	·000000	−·000001	−·000007	−·000004	·000000	−·000008	−·000007	−·000009	−·000012	−·000001	−·000006
6	−·000007	−·000007	+·000005	−·000005	+·000001	−·000007	−·000003	−·000007	−·000011	−·000006	−·000014	−·000012	−·000005	−·000009
7	·000000	−·000002	+·000006	−·000009	−·000002	·000000	−·000001	−·000009	−·000016	+·000002	−·000006	−·000005	−·000010	−·000008
8	·000000	·000000	·000000	−·000006	·000000	−·000003	−·000002	−·000001	−·000002	−·000001	+·000001	−·000002	·000000	−·000001
9	+·000006	+·000003	−·000002	+·000003	+·000001	+·000005	+·000002	+·000002	+·000004	−·000002	+·000008	+·000004	+·000002	+·000003
10	+·000005	+·000006	−·000010	·000000	−·000005	+·000006	−·000001	+·000006	−·000002	·000000	+·000005	·000000	+·000004	+·000002
11	+·000001	+·000001	·000000	−·000003	+·000001	−·000001	·000000	+·000003	−·000005	+·000006	+·000002	+·000002	+·000001	+·000001
12	−·000005	+·000006	+·000002	+·000003	+·000005	−·000002	+·000001	−·000001	−·000001	−·000007	+·000007	−·000004	+·000002	−·000001
13	−·000005	+·000003	+·000003	+·000001	+·000004	−·000003	·000000	−·000008	−·000002	−·000003	+·000001	−·000003	−·000004	−·000003
14	−·000006	−·000001	+·000005	+·000003	+·000004	−·000004	·000000	−·000013	·000000	−·000016	+·000002	−·000008	−·000007	−·000007
15	−·000002	−·000002	+·000006	+·000002	+·000005	−·000002	+·000001	−·000010	−·000007	−·000012	+·000006	−·000005	−·000007	−·000006
16	−·000001	−·000007	+·000008	−·000001	+·000006	−·000007	·000000	−·000007	−·000007	−·000004	+·000003	−·000004	−·000004	−·000004
17	+·000003	−·000008	+·000008	+·000010	+·000009	·000000	+·000005	−·000015	−·000003	−·000003	+·000004	·000000	−·000009	−·000005
18	+·000012	+·000006	+·000010	+·000013	+·000008	+·000010	+·000010	+·000007	−·000002	−·000002	+·000010	+·000001	+·000006	+·000002
19	+·000016	+·000007	+·000010	+·000004	+·000013	+·000006	+·000009	+·000012	+·000008	+·000001	+·000008	+·000005	+·000009	+·000007
20	+·000022	+·000013	·000000	+·000001	+·000006	+·000013	+·000009	+·000024	+·000027	+·000010	+·000003	+·000013	+·000019	+·000016
21	+·000031	+·000017	·000000	+·000016	+·000007	+·000025	+·000015	+·000019	+·000029	+·000027	+·000013	+·000021	+·000022	+·000022
22	+·000024	+·000010	−·000009	·000000	−·000002	+·000016	+·000006	+·000019	+·000019	+·000010	+·000006	+·000013	+·000014	+·000013
23	+·000019	+·000012	−·000002	−·000004	−·000004	+·000017	+·000006	+·000008	+·000011	+·000012	+·000018	+·000015	+·000009	+·000012
Number of lunar-days' observations in abstract	245	240	274	251	527	483	1010	202	196	198	218	402	412	814

TABLE VI.—Horizontal Force at Bombay, showing the Mean Lunar Diurnal Variation at First Quarter and Three-eighths Phase in each Quarter of the Year.

Phase of moon.	First quarter.							Three-eighths.						
Bombay lunar hours.	November to January.	February to April.	May to July.	August to October.	April to September.	October to March.	Year.	November to January.	February to April.	May to July.	August to October.	April to September.	October to March.	Year.
0	+·000005	·000000	−·000002	−·000002	+·000001	+·000001	·000000	+·000004	+·000009	·000000	·000000	+·000002	+·000004	+·000003
1	+·000005	+·000006	·000000	+·000006	+·000001	+·000009	+·000004	+·000011	−·000002	+·000002	+·000005	+·000007	+·000002	+·000004
2	+·000007	+·000001	−·000010	−·000004	−·000008	+·000005	−·000002	−·000001	−·000005	+·000010	−·000003	+·000008	−·000008	·000000
3	−·000002	+·000001	−·000009	−·000007	−·000009	+·000002	−·000004	+·000013	−·000004	−·000002	−·000002	+·000003	−·000001	+·000001
4	+·000012	−·000007	−·000004	−·000006	−·000007	+·000003	−·000002	+·000003	+·000001	−·000001	−·000005	−·000002	+·000001	−·000001
5	+·000009	−·000010	−·000004	−·000012	−·000007	·000000	−·000004	+·000005	+·000008	−·000001	+·000007	+·000004	+·000006	+·000005
6	+·000002	−·000002	+·000004	−·000016	−·000003	−·000002	−·000003	+·000011	+·000012	+·000004	+·000009	+·000007	+·000011	+·000009
7	+·000005	·000000	−·000002	−·000011	−·000005	+·000001	−·000003	+·000015	+·000012	−·000002	+·000008	+·000003	+·000013	+·000008
8	+·000004	−·000004	−·000005	−·000002	−·000004	+·000002	−·000002	+·000019	+·000017	−·000005	+·000010	+·000003	+·000017	+·000010
9	+·000010	−·000002	−·000001	+·000001	·000000	+·000006	+·000002	+·000014	+·000010	·000000	+·000013	+·000008	+·000010	+·000009
10	+·000010	+·000004	·000000	−·000002	+·000001	+·000006	+·000003	+·000016	+·000013	+·000007	+·000014	+·000011	+·000014	+·000012
11	+·000011	+·000004	−·000002	−·000007	−·000003	+·000007	+·000001	+·000013	+·000010	+·000007	+·000008	+·000009	+·000010	+·000010
12	+·000006	+·000001	+·000004	−·000004	·000000	+·000004	+·000001	−·000009	−·000001	−·000001	+·000003	−·000003	−·000001	−·000002
13	−·000004	−·000008	−·000003	−·000003	−·000005	−·000002	−·000005	−·000024	−·000009	+·000003	−·000010	−·000008	−·000011	−·000010
14	−·000015	−·000009	−·000010	−·000008	−·000009	−·000011	−·000011	−·000025	−·000022	−·000002	−·000019	−·000014	−·000020	−·000017
15	−·000029	−·000022	−·000013	−·000006	−·000011	−·000023	−·000018	−·000029	−·000025	+·000001	−·000021	−·000013	−·000023	−·000018
16	−·000022	−·000016	−·000001	+·000009	+·000005	−·000020	−·000008	−·000025	−·000014	−·000002	−·000015	−·000006	−·000021	−·000014
17	−·000013	−·000016	−·000012	+·000011	−·000002	−·000015	−·000009	−·000027	−·000001	−·000018	−·000004	−·000011	−·000015	−·000013
18	−·000014	−·000002	−·000001	+·000014	+·000008	−·000009	−·000001	−·0000 7	−·000003	−·000011	−·000007	−·000010	−·000005	−·000007
19	−·000010	+·000004	+·000006	+·000022	+·000013	−·000002	+·000005	−·000001	−·000009	−·000007	+·000004	−·000004	−·000002	−·000003
20	+·000010	+·000009	+·000012	+·000002	+·000008	+·000009	+·000008	+·000009	−·000004	−·000002	+·000009	+·000004	+·000003	+·000003
21	+·000010	+·000027	+·000019	+·000012	+·000018	+·000016	+·000016	+·000006	−·000004	+·000004	−·000003	·000000	+·000002	+·000001
22	+·000010	+·000017	+·000020	+·000016	+·000020	+·000011	+·000015	+·000006	+·000004	+·000003	+·000001	+·000001	+·000007	+·000004
23	+·000009	+·000015	+·000007	+·000001	+·000009	+·000008	+·000008	+·000014	+·000015	+·000005	·000000	+·000006	+·000011	+·000008
Number of lunar days' observations in abstract	263	252	272	268	541	514	1055	205	198	220	209	416	416	832

TABLE VII.—Horizontal Force at Bombay, showing the Mean Lunar Diurnal Variation at Full Moon and Five-eighths Phase in each Quarter of the Year.

Phase of moon.	Full moon.							Five-eighths.						
Bombay lunar hours.	November to January.	February to April.	May to July.	August to October.	April to September.	October to March.	Year.	November to January.	February to April.	May to July.	August to October.	April to September.	October to March.	Year.
0	+·000002	−·000006	·000000	−·000003	+·000001	−·000007	−·000003	·000000	−·000018	+·000001	−·000002	·000000	−·000009	−·000004
1	+·000006	−·000008	−·000003	·000000	−·000004	−·000001	−·000001	−·000003	−·000009	−·000003	−·000004	−·000002	−·000006	−·000004
2	−·000006	−·000007	−·000003	−·000010	−·000005	−·000008	−·000006	−·000012	−·000007	−·000005	−·000007	−·000004	−·000010	−·000007
3	−·000007	−·000008	−·000003	−·000005	−·000003	−·000007	−·000005	−·000019	−·000007	+·000004	−·000003	·000000	−·000012	−·000006
4	−·000008	·000000	+·000003	−·000004	+·000002	−·000004	−·000001	−·000012	−·000007	+·000005	−·000005	·000000	−·000009	−·000004
5	−·000001	−·000003	−·000002	+·000007	+·000005	−·000004	+·000001	·000000	·000000	+·000015	+·000004	+·000005	+·000006	+·000006
6	+·000001	+·000009	·000000	+·000003	+·000004	+·000002	+·000008	+·000014	−·000007	+·000002	−·000002	−·000001	+·000005	+·000002
7	+·000002	+·000010	+·000003	−·000001	+·000002	+·000005	+·000004	+·000029	+·000020	+·000007	+·000011	+·000006	+·000027	+·000017
8	+·000019	+·000011	+·000002	+·000005	+·000003	+·000016	+·000009	+·000036	+·000021	+·000005	+·000012	+·000006	+·000031	+·000019
9	+·000025	+·000015	+·000009	+·000013	+·000011	+·000022	+·000017	+·000033	+·000010	+·000001	+·000029	+·000008	+·000024	+·000016
10	+·000027	+·000014	+·000001	+·000010	+·000004	+·000022	+·000013	+·000023	+·000020	−·000002	+·000009	+·000006	+·000019	+·000013
11	+·000011	+·000005	+·000003	+·000006	+·000001	+·000011	+·000006	+·000010	+·000022	−·000006	·000000	−·000002	+·000015	+·000007
12	−·000007	+·000009	+·000007	−·000004	+·000005	−·000002	+·000001	+·000005	+·000017	−·000009	+·000011	+·000004	+·000027	+·000006
13	−·000008	−·000001	+·000004	−·000002	·000000	−·000004	−·000002	+·000007	+·000005	−·000011	+·000014	−·000001	+·000009	+·000004
14	−·000020	−·000011	−·000007	−·000004	−·000011	−·000009	−·000010	−·000011	+·000002	−·000009	−·000005	−·000009	−·000003	−·000006
15	−·000024	−·000009	−·000004	−·000003	−·000007	−·000012	−·000010	−·000023	·000000	−·000007	−·000007	−·000007	−·000012	−·000009
16	−·000013	−·000007	−·000002	−·000004	−·000004	−·000009	−·000006	−·000017	+·000003	−·000007	−·000004	−·000005	−·000009	−·000006
17	−·000003	−·000001	·000000	−·000003	−·000002	−·000001	−·000001	−·000015	−·000005	−·000002	−·000006	−·000002	−·000012	−·000007
18	−·000007	−·000009	−·000002	−·000006	−·000004	−·000007	−·000005	−·000017	−·000004	+·000006	−·000003	+·000001	−·000011	−·000005
19	−·000001	−·000009	+·000002	·000000	+·000004	−·000007	−·000001	−·000016	−·000018	+·000004	−·000017	−·000003	−·000019	−·000011
20	−·000001	−·000010	·000000	−·000001	·000000	−·000005	−·000003	−·000005	−·000009	+·000006	−·000009	+·000002	−·000010	−·000004
21	−·000002	+·000005	−·000008	−·000003	−·000002	−·000001	−·000002	−·000007	−·000010	+·000001	−·000008	−·000002	−·000009	−·000005
22	+·000004	·000000	−·000005	−·000001	−·000005	+·000004	·000000	+·000004	−·000008	+·000004	−·000003	−·000001	−·000001	·000000
23	+·000009	·000000	−·000003	+·000005	−·000001	+·000007	+·000003	−·000001	−·000006	+·000004	−·000006	−·000002	−·000004	−·000003
Number of lunar days' observations in abstract	253	230	258	241	501	481	982	197	188	209	207	412	389	801

TABLE VIII.—Horizontal Force at Bombay, showing the Mean Lunar Diurnal Variation at Last Quarter and Seven-eighths Phase in each Quarter of the Year.

Phase of moon.	Last quarter.							Seven-eighths.						
Bombay lunar hours.	November to January.	February to April.	May to July.	August to October.	April to September.	October to March.	Year.	November to January.	February to April.	May to July.	August to October.	April to September.	October to March.	Year.
0	−·000008	−·000004	−·000007	+·000001	−·000005	−·000004	−·000004	−·000013	−·000012	−·000012	+·000002	−·000010	−·000008	−·000009
1	−·000006	·000000	−·000007	−·000008	−·000008	−·000003	−·000005	−·000025	−·000025	−·000018	+·000004	−·000011	−·000021	−·000016
2	−·000018	−·000002	−·000002	−·000001	−·000002	−·000010	−·000006	−·000045	−·000026	−·000020	−·000013	−·000019	−·000034	−·000027
3	−·000023	+·000006	+·000013	−·000016	+·000005	−·000016	−·000005	−·000043	−·000021	−·000016	−·000017	−·000020	−·000030	−·000025
4	−·000023	+·000003	·000000	−·000006	+·000003	−·000017	−·000007	−·000030	−·000029	−·000007	−·000021	−·000014	−·000030	−·000022
5	−·000004	−·000003	+·000009	−·000008	+·000005	−·000008	−·000001	−·000013	−·000028	−·000017	−·000012	−·000015	−·000020	−·000017
6	+·000014	+·000007	−·000002	−·000011	−·000002	+·000006	+·000002	+·000001	−·000007	−·000022	−·000018	−·000022	−·000001	−·000011
7	+·000032	+·000003	−·000004	−·000003	·000000	+·000014	+·000007	−·000003	+·000003	−·000011	+·000002	−·000003	−·000002	−·000003
8	+·000028	−·000005	+·000010	+·000002	+·000008	+·000010	+·000009	+·000020	+·000011	−·000004	+·000001	−·000002	+·000016	+·000006
9	+·000026	−·000002	+·000008	+·000006	+·000004	+·000015	+·000009	+·000020	·000000	−·000002	+·000009	+·000002	+·000011	+·000007
10	+·000021	−·000003	+·000002	−·000009	−·000003	+·000009	+·000003	+·000016	·000000	+·000003	+·000009	+·000002	+·000012	+·000007
11	+·000009	+·000002	+·000006	−·000001	+·000003	+·000005	+·000004	+·000017	+·000002	·000000	+·000014	+·000004	+·000013	+·000009
12	+·000005	−·000011	−·000003	+·000003	−·000003	·000000	−·000001	+·000017	+·000022	+·000007	+·000005	+·000009	+·000016	+·000012
13	−·000001	−·000003	−·000004	+·000004	−·000002	·000000	−·000001	+·000021	+·000022	+·000008	+·000008	+·000009	+·000020	+·000014
14	−·000003	+·000002	+·000002	+·000002	+·000002	·000000	+·000001	+·000004	+·000019	+·000012	+·000007	+·000010	+·000010	+·000010
15	−·000009	+·000002	−·000001	+·000006	+·000001	−·000003	·000000	·000000	+·000019	+·000008	−·000001	+·000005	+·000007	+·000006
16	−·000007	−·000002	+·000002	+·000009	+·000002	−·000001	+·000001	+·000011	+·000002	+·000011	+·000001	+·000006	+·000006	+·000006
17	−·000011	−·000007	−·000002	+·000004	−·000004	−·000008	−·000004	+·000009	+·000004	+·000005	+·000012	+·000009	+·000006	+·000007
18	+·000003	·000000	−·000004	+·000003	−·000001	+·000001	·000000	·000000	+·000014	+·000012	+·000004	+·000010	+·000004	+·000007
19	−·000006	+·000011	−·000006	+·000007	·000000	+·000002	+·000001	+·000001	+·000012	+·000012	+·000002	+·000010	+·000002	+·000006
20	−·000003	+·000010	−·000003	−·000004	−·000004	+·000004	·000000	+·000006	+·000008	+·000019	+·000005	+·000012	+·000007	+·000009
21	−·000001	+·000007	−·000004	+·000007	−·000001	+·000005	+·000002	+·000010	+·000010	+·000017	+·000006	+·000012	+·000010	+·000011
22	−·000006	+·000002	−·000004	+·000008	−·000001	+·000001	·000000	+·000005	+·000007	+·000015	+·000005	+·000010	+·000005	+·000008
23	−·000015	−·000005	−·000005	+·000012	−·000002	−·000005	−·000003	+·000004	−·000006	+·000010	−·000007	·000000	+·000001	·000000
Number of lunar days' observations in abstract	255	250	266	267	532	506	1038	214	190	208	209	413	403	816

7. Curves were now constructed to represent the variations otherwise expressed by the hourly excesses for the several seasons and phases, and a consideration of them led to the formation of the hypothesis that the bulk of the phenomenon dealt with is, properly speaking, not a lunar diurnal variation, but a solar diurnal variation that depends on the relative positions of the sun and moon, a variation such that it may be expressed, for any one season, by the formula

$$f_{c.2}(h)\cos 2\left(\frac{2\pi}{\mathrm{P}}t\right)+f_{s.2}(h)\sin 2\left(\frac{2\pi}{\mathrm{P}}t\right),$$

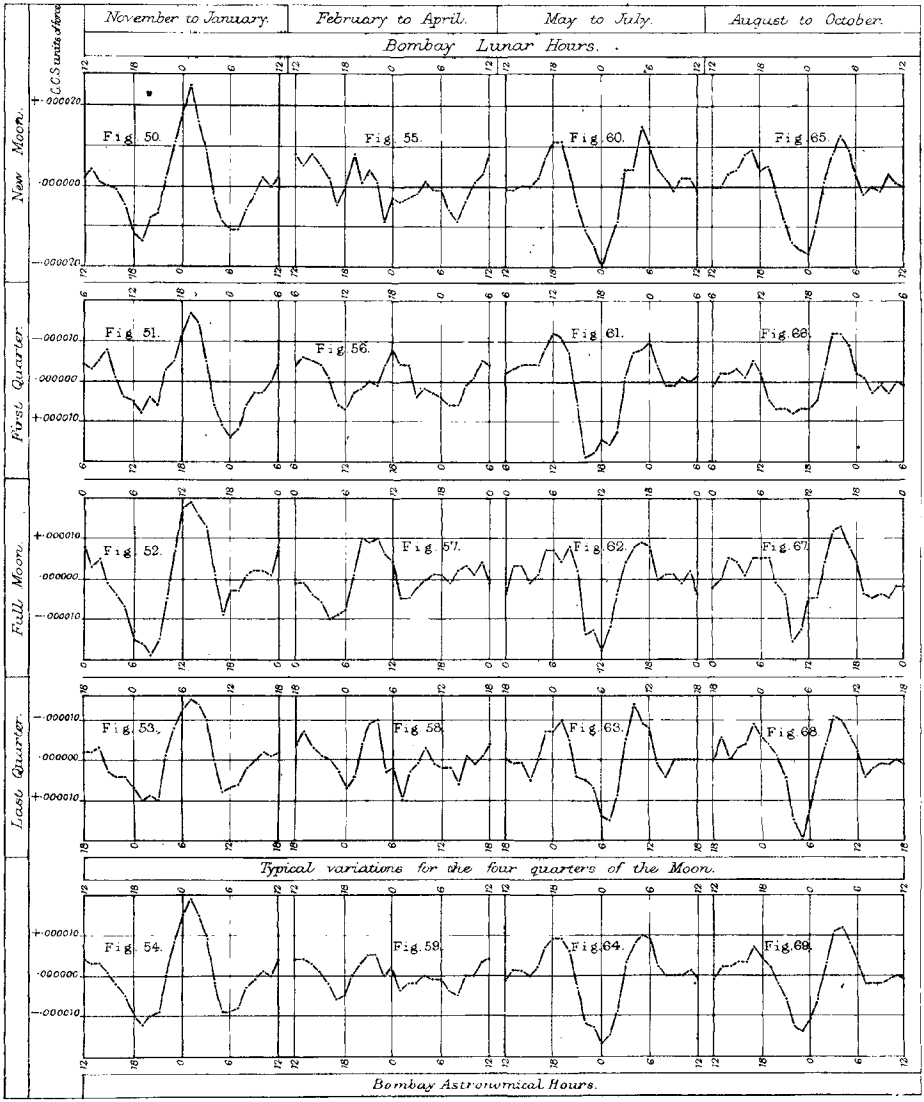
where h is the hour of the solar day, P the mean period of a lunation in mean solar days, and t the age of the moon in mean solar days; and $f_{c.2}(h), f_{s.2}(h)$, are the observed variations at new moon and when the moon has the age one-eighth of a lunation respectively. It will presently be seen that, though the typical variations $\{f(h)\}$ of one season differ from those of another, this hypothesis holds good generally in each quarter of the year separately.

Of the two characteristics of the curves that pointed in the direction of the formula, the first was the general fact that the great movements occur in them, as in curves of the mean solar diurnal variations for full lunations, in the solar *day hours*, and the night hours are relatively quiescent; or, viewed in another aspect, the significant movements occur at all hours of the lunar day in the course of a lunation, and appear earlier and earlier as the age of the moon increases. And the second characteristic was that the curves, regarded as solar diurnal curves, have generally the same form and range at intervals of half a lunation, and opposite forms at intervals of a quarter of a lunation; and this with reference separately to each of the two magnetic elements and to each season of the year.

[7*a*. It may be explained here that in the first reductions of the Bombay declination observations the categories into which the days were divided had reference (1) to the four seasons of the year, (2) to four positions of the moon in declination, and (3) to the four quarters of the moon—*not* to eight phases as in the later reductions. A short account of a first instalment of the results of these reductions, dealing with the observations of the years 1861 to 1863, was read before the Royal Society on the 2nd February, 1872; but it was the results of these earlier reductions for the full period of twenty-five years that suggested the idea of the luni-solar variation as expressed by the formula given in the last paragraph, and the computation and curving of the lunar diurnal variations of each category for that period were not completed till the 4th March, 1873. How very definite the suggestion was may be seen from the curves of figs. 50 to 53, 55 to 58, 60 to 63, and 65 to 68, which represent the lunar diurnal variations for the sixteen principal categories. To facilitate comparison, the curves for the different phases of the same season are placed under one another, the lunar time scales are arranged so that the beginning and end of the curves should correspond approximately to the same solar time, and the force scales for first quarter

Colaba Observatory, Bombay.

Curves representing the lunar diurnal variations of declination for the four quarters of the Moon in each of four seasons of the year, and the typical variation for each season.



West, Newman & Co. lith.

and last quarter are inverted in comparison with the force scales for new moon and full moon. With the curves thus arranged, the four, occupying each vertical curve-form, and of which the fifth curve is, in each case, the type (or average), can be taken into view at a single glance, and the degree of their similarity is thus easily recognised. But similarity in these curves means the same thing as the second characteristic of the curves of lunar diurnal variations, which is expressed in words in the last paragraph as follows—the curves, regarded as solar diurnal curves, have generally the same form and range at intervals of half a lunation, and opposite forms at intervals of a quarter of a lunation. The similarity is very pronounced in all seasons except the transition one—February to April—in which the inversion of character of the variations is in progress.—23rd September, 1886.]

8. It now became an object to adapt the results already obtained, which have reference to the lunar day, to the determination of the data $f_{c,2}(h)$ and $f_{s,2}(h)$ of the formula; for this purpose the following process was adopted.

As the lunar day roughly approximates to the same length as the solar day, we suppose the observed lunar diurnal variation at new moon to imply with rough approximation a solar diurnal variation of the same character; and we enter the hourly excesses in a Table having solar hours, from 0 to 23, marked at the top of the columns; under these numbers we enter the excesses of full moon, placing the number belonging to the 0th hour of lunar time under the 12th hour of solar time, and we then take the sums of the two sets of numbers. Again, we enter the excesses of first quarter, placing the number belonging to the 0th hour of lunar time under the 6th hour of solar time; and under these we enter the excesses of last quarter, placing the number of the 0th hour of lunar time under the 18th hour of solar time, and we then take the sum of these two sets of numbers; next, we subtract the latter sums from the former, and divide the results by 4, calling the series of quotients the typical variation for the quarters of the moon, that is $f_{c,2}(h)$. Similarly, substituting the hourly excesses of the phases one-eighth, three-eighths, five-eighths, and seven-eighths for those of new moon, first quarter, full moon, and last quarter respectively, we obtain the typical variation for the eighths phases, that is $f_{s,2}(h)$. In this way, of which an example will now be given, have been obtained the typical variations shown in Tables 9 and 10, using as data the numbers in Column 2 of Tables 1 to 4 for the first line of Table 9, in Column 3 of Tables 1 to 4 for the second line of Table 9, and so on.

CALCULATION of the typical Variation of Declination for the Quarters of the

	Lunar diurnal variation for—	Bombay									
		0	1	2	3	4	5	6	7	8	9
a	New Moon	+·000016	+·000018	+·000008	+·000006	−·000004	−·000008	−·000012	−·000011	−·000006	−·000003
b	Full Moon	+·000008	+·000012	+·000020	+·000010	−·000005	−·000007	+·000001	+·000006	+·000006	+·000003
c	$a+b$	+·000024	+·000030	+·000028	+·000016	−·000009	−·000015	−·000011	−·000005	·000000	·000000
d	First Quarter	−·000015	−·000015	−·000026	·000000	+·000013	+·000016	+·000018	+·000012	+·000006	−·000002
e	Last Quarter	−·000018	−·000025	−·000029	−·000014	·000000	+·000010	+·000011	+·000007	+·000005	+·000001
f	$d+e$	−·000033	−·000040	−·000055	−·000014	+·000013	+·000026	+·000029	+·000019	+·000011	−·000001
g	$c-f$	+·000057	+·000073	+·000083	+·000030	−·000022	−·000041	−·000040	−·000024	−·000011	+·000001
h	$\frac{1}{2}(c-f)=f_{c.2}(h)$.	+·000014	+·000018	+·000021	+·000007	−·000005	−·000010	−·000010	−·000006	−·000003	·000000

TABLE 9.—Showing the typical Variations $f_{c.2}(h)$ and $f_{s.2}(h)$

	Bombay Astronomical Hours.	0	1	2	3	4	5	6	7	8	9
$f_{c.2}(h)$	November to January . . .	+·000014	+·000018	+·000021	+·000007	−·000005	−·000010	−·000010	−·000006	−·000003	·000000
	February to April	+·000003	−·000001	+·000001	−·000002	·000000	−·000002	−·000005	−·000005	−·000005	−·000001
	May to July	−·000014	−·000013	−·000008	+·000001	+·000008	+·000011	+·000007	·000000	·000000	+·000001
	August to October	−·000016	−·000016	−·000004	+·000009	+·000014	+·000010	+·000004	·000000	−·000001	−·000001
$f_{s.2}(h)$	November to January . . .	−·000011	−·000005	+·000005	+·000009	+·000017	+·000013	+·000004	−·000001	·000000	−·000002
	February to April	+·000005	+·000001	−·000008	−·000004	−·000001	+·000003	+·000003	+·000004	−·000001	−·000003
	May to July	−·000004	−·000012	−·000015	−·000023	−·000011	−·000002	+·000005	+·000004	+·000003	+·000001
	August to October	−·000004	−·000015	−·000013	−·000011	−·000007	+·000008	+·000003	+·000004	·000000	−·000001

TABLE 10.—Showing the typical Variations $f_{c.2}(h)$ and $f_{s.2}(h)$

	Bombay Astronomical Hours.	0	1	2	3	4	5	6	7	8	9
$f_{c.2}(h)$	November to January . . .	−·000004	−·000011	−·000021	−·000023	−·000016	−·000008	−·000006	−·000001	−·000001	+·000004
	February to April	+·000001	−·000003	−·000006	−·000013	−·000010	−·000007	−·000001	−·000003	−·000003	+·000001
	May to July	+·000001	−·000002	−·000009	−·000010	−·000008	−·000003	+·000002	+·000003	+·000002	·000000
	August to October	−·000004	−·000005	−·000003	−·000008	−·000006	−·000001	−·000003	−·000005	−·000001	·000000
$f_{s.2}(h)$	November to January . . .	+·000031	+·000024	+·000014	+·000004	·000000	−·000011	−·000016	−·000009	−·000011	−·000011
	February to April	+·000021	+·000020	+·000015	+·000006	+·000001	−·000001	·000000	−·000003	−·000007	−·000011
	May to July	+·000011	+·000004	+·000010	+·000009	+·000002	·000000	−·000004	−·000005	−·000003	−·000001
	August to October	+·000017	+·000013	+·000008	+·000006	−·000002	−·000010	−·000008	−·000005	−·000007	−·000005

The variations of Tables 9 and

Moon in the Quarter November to January—that is, of the Variation $f_{c.2}(h)$.

Astronomical Hours.

10	11	12	13	14	15	16	17	18	19	20	21	22	23
−·000001	+·000004	+·000004	+·000006	+·000004	+·000005	+·000001	−·000004	−·000015	−·000009	−·000001	−·000008	−·000006	+·000003
+·000002	+·000004	+·000008	+·000004	+·000001	−·000006	−·000007	−·000009	−·000015	−·000011	−·000018	−·000017	+·000001	+·000009
+·000001	+·000008	+·000012	+·000010	+·000005	−·000001	−·000006	−·000013	−·000031	−·000026	−·000019	−·000025	−·000005	+·000017
+·000002	−·000001	−·000006	−·000002	−·000006	−·000009	−·000008	+·000004	+·000006	+·000006	+·000006	+·000008	−·000002	−·000004
+·000003	·000000	−·000003	·000000	+·000001	+·000006	+·000010	+·000011	+·000010	+·000009	+·000011	+·000014	·000000	−·000011
+·000005	−·000001	−·000008	−·000002	−·000005	−·000003	+·000005	+·000015	+·000016	+·000015	+·000017	+·000022	−·000002	−·000015
−·000004	+·000009	+·000021	+·000012	+·000010	+·000002	−·000011	−·000028	−·000047	−·000043	−·000036	−·000047	−·000003	+·000032
−·000001	+·000002	+·000005	+·000003	+·000002	·000000	−·000003	−·000007	−·000012	−·000009	−·000009	−·000012	−·000001	+·000008

of Declination at Bombay for each Quarter of the Year.

10	11	12	13	14	15	16	17	18	19	20	21	22	23
−·000001	+·000002	+·000005	+·000003	+·000002	·000000	−·000003	−·000007	−·000012	−·000009	−·000009	−·000012	−·000001	+·000008
−·000002	·000000	+·000003	+·000001	+·000002	+·000001	−·000002	−·000004	−·000003	+·000004	+·000002	+·000006	+·000008	+·000051
+·000001	+·000001	−·000001	·000000	+·000001	·000000	+·000001	+·000007	+·000009	+·000012	+·000005	−·000006	−·000014	−·000011
−·000002	+·000002	+·000001	+·000003	+·000004	+·000004	+·000004	+·000007	+·000007	+·000007	+·000003	−·000007	−·000015	−·000019
−·000003	−·000002	·000000	+·000001	+·000004	+·000003	+·000006	+·000007	+·000006	+·000001	−·000006	−·000014	−·000016	−·000011
−·000003	−·000003	+·000001	+·000001	+·000006	+·000005	+·000004	·000000	−·000002	−·000005	·000000	−·000005	·000000	−·000002
·000000	·000000	+·000002	+·000003	+·000002	·000000	−·000001	−·000004	+·000001	+·000010	+·000011	+·000012	+·000011	+·000005
+·000001	−·000001	−·000004	−·000002	+·000001	+·000002	+·000002	+·000002	+·000004	+·000007	+·000017	+·000009	+·000003	−·000002

of Horizontal Force at Bombay for each Quarter of the Year.

10	11	12	13	14	15	16	17	18	19	20	21	22	23
+·000001	+·000003	−·000002	·000000	−·000003	−·000004	−·000002	+·000001	+·000004	+·000007	+·000019	+·000027	+·000024	+·000013
+·000004	+·000004	·000000	−·000004	−·000003	−·000004	−·000003	−·000001	+·000004	+·000006	+·000009	+·000012	+·000009	+·000009
−·000003	+·000001	·000000	+·000002	+·000002	+·000002	+·000004	+·000003	+·000003	+·000006	+·000003	+·000002	−·000002	+·000001
−·000001	+·000002	+·000002	+·000001	·000000	−·000003	−·000003	+·000008	+·000005	+·000003	+·000004	+·000014	+·000022	·000000
−·000014	−·000002	−·000004	−·000001	−·000003	−·000003	−·000007	−·000012	−·000013	−·000010	−·000008	+·000011	+·000022	+·000032
−·000013	−·000006	−·000005	−·000003	−·000006	−·000011	−·000009	−·000008	−·000008	−·000008	−·000002	+·000001	+·000015	+·000024
−·000001	−·000004	−·000002	−·000001	+·000001	−·000005	−·000004	−·000009	−·000006	−·000003	−·000001	+·000003	+·000008	+·000009
−·000009	−·000003	+·000001	+·000001	−·000006	−·000002	−·000003	−·000005	−·000004	−·000005	+·000002	+·000001	+·000005	+·000012

10 are curved in figs. 1 to 16.

9. Considering now the typical variation curves (figs. 1 to 16), we see that those which are the most definite and systematic in character, and have the largest range, whether of declination or horizontal force, are for the winter season ; and, in the case of each type, the curves for the other seasons are definitely related to these. Thus, as to declination, between winter and summer there is an inversion of the types of both figs. 1 and 5 ; and the type-curves of the transition period, the spring season, have but a small range, and in them the prominent features of the winter curves are all but obliterated. Necessarily there is also a return inversion of the type in another season, and it occurs between mid-autumn and mid-winter. On the other hand, the horizontal force types (figs. 9 to 16), although of largest range in winter, are never reversed in character, but contract only to a minimum range, which is reached in the summer season.

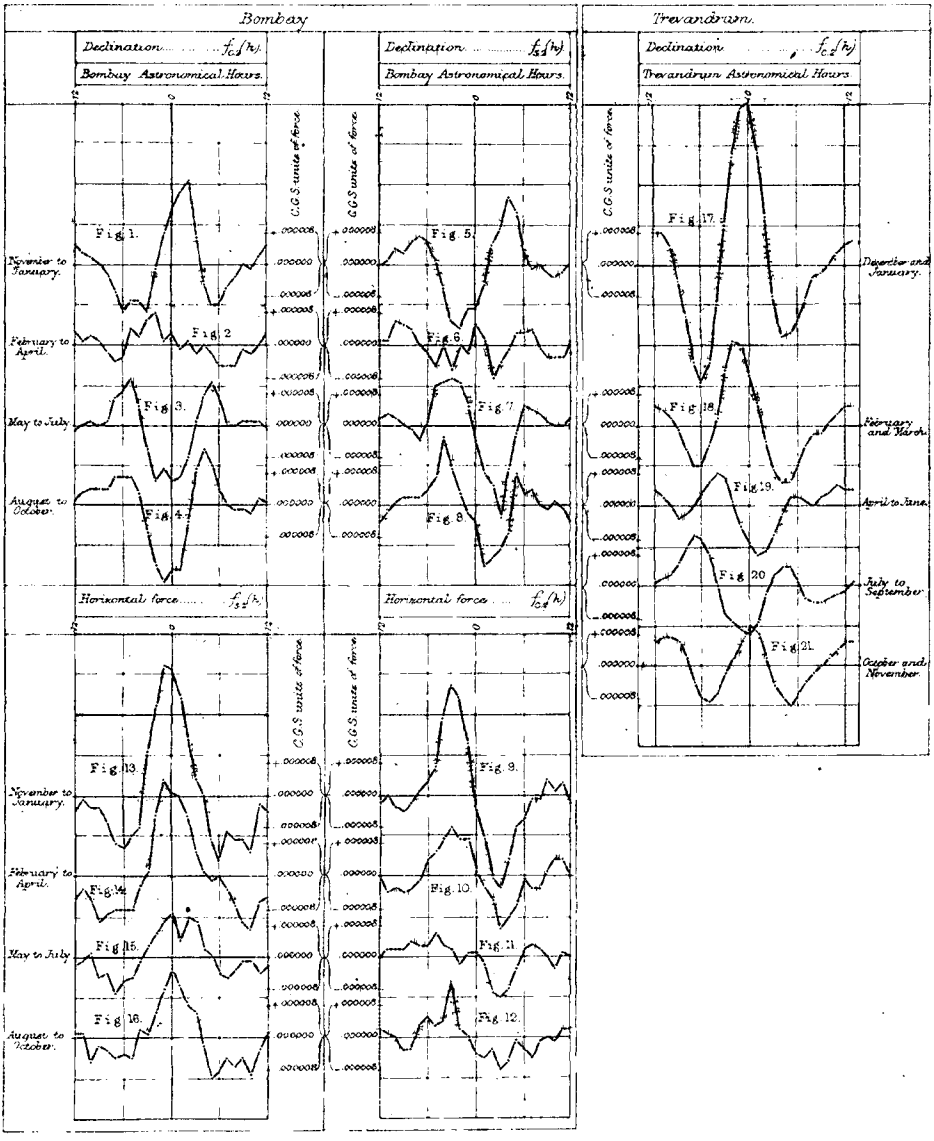
The typical diurnal variation for November to January of horizontal force at new moon (fig. 9), and that of declination at the one-eighth phase reversed to correspond to the seven-eighths phase (fig. 5 reversed), have generally a maximum about three hours before noon, a minimum about three hours after noon, and are nearly *nil* for three or four hours before and after midnight; those of declination at new moon (fig. 1) and of horizontal force at the one-eighth phase (fig. 13) have a principal upward inflexion with a turning point about noon, two nearly equal downward inflexions with turning points about five or six hours before and after noon, and little or no departure from the mean line for three or four hours before and after midnight. For the summer and autumn seasons similar descriptions of the typical diurnal variations would apply, providing due allowance were made for the double reversal in the course of the year of the declination types.

Comparing figs. 3 and 4 with 1, and figs. 7 and 8 with 5, all declination curves, it may be noted, as a minor characteristic, that the principal inflexions occur generally somewhat earlier in summer and autumn than in winter.

10. The general similarity of character of figs. 1 and 13, representing the $f_{c.2}(h)$ and $f_{s.2}(h)$ data of our formula for the declination and horizontal force respectively, and the opposition of character of figs. 5 and 9, representing conversely the $f_{s.2}(h)$ and $f_{c.2}(h)$ data for the elements taken in the same order, call for further consideration. These relations may be translated into a statement that, in the winter season, the luni-solar variation of declination due to new moon is similar to the luni-solar variation of horizontal force due to the one-eighth phase ; and the luni-solar variation of horizontal force due to new moon is similar to the luni-solar variation of declination due to the seven-eighths phase. In other words, the luni-solar variation of declination due to any phase of the moon is similar to the luni-solar variation of horizontal force due to a phase later by one-eighth of a lunation. In the summer and autumn seasons it is, on the other hand, the luni-solar variations of horizontal force that precede by one-eighth of a lunation the similar variations of declination ; this will be seen by comparing figs. 11 and 12 with figs. 7 and 8, and figs. 15 and 16 with figs. 3 and 4 reversed.

Colaba Observatory, Bombay

Typical variations of declination and horizontal force at Bombay and of declination at Trevandrum



The fact of harmonious relations of this kind being found to subsist between results derived from long series of observations of two *independent* instruments, we cannot but regard as strong testimony to the reality of the phenomena now brought to light; neither can we refrain from claiming for such results a modest place amongst the phenomenal laws of terrestrial magnetism that must ultimately stand in the same relation to a physical theory of terrestrial magnetism that KEPLER'S laws stand in towards the theory of gravitation.

11. At this stage the question was put—With what approach to completeness does the typical variation in each case represent the four actual variations from which it was derived, or how much of a mean lunar variation is there in these over and above the typical variation? Subtracting (say) $f_{c,2}(h)$ from the observed variation at new moon and full moon, and adding it to the observed variation at first quarter and last quarter in such a way that the 0th, 6th, 12th, and 18th hours of $f_{c,2}(h)$ are compared with the 0th hour of new moon, first quarter, full moon, and last quarter respectively; the 1st, 7th, 13th, and 19th hours of $f_{c,2}(h)$ with the 1st hour of new moon, first quarter, &c., respectively, and so on, we obtain four sets of residual variations, each commencing with the 0th hour of the lunar day; and, taking the mean of these four, we obtain the residual lunar diurnal variation that is left after appropriately eliminating the typical variation for the four quarters. A similar procedure, using the observed variations at the eighths phases, gives corresponding residual variations for the eighths phases.

12. On curving these residuals for each quarter of the year—eight in all for each magnetic element—and comparing each curve with the corresponding typical variation curve, they were all found to be of small relative range, but most of them had a definite character, in which the principal harmonic element was that which has the lunar day for its period. In the latter fact we found a suggestion that, although our formula disposes of the bulk of the phenomena for which an expression is to be found, the addition to it of two more independent terms would not only make it mathematically more complete, but would render it further expressive of an otherwise neglected, but significant, element in the luni-solar variation. Making this addition, the formula becomes

$$f_{c,1}(h)\cos\left(\frac{2\pi}{\mathrm{P}}t\right)+f_{s,1}(h)\sin\left(\frac{2\pi}{\mathrm{P}}t\right)+f_{c,2}(h)\cos 2\left(\frac{2\pi}{\mathrm{P}}t\right)+f_{s,2}(h)\sin 2\left(\frac{2\pi}{\mathrm{P}}t\right),$$*

* If ϕ be written for the angle $\frac{2\pi}{\mathrm{P}}t$, and θ for the angle $\frac{2\pi}{24}h$, the formula may easily be transformed into

$$\mathrm{F}_{c,1}(\phi)\cos\left(\frac{2\pi}{24}h\right)+\mathrm{F}_{s,1}(\phi)\sin\left(\frac{2\pi}{24}h\right)+\mathrm{F}_{c,2}(\phi)\cos 2\left(\frac{2\pi}{24}h\right)+\mathrm{F}_{s,2}(\phi)\sin 2\left(\frac{2\pi}{24}h\right),$$

in which $\mathrm{F}_{c,1}(\phi)$, $\mathrm{F}_{s,1}(\phi)$ are variations, of constant types, having the period of a lunation, and $\mathrm{F}_{c,2}(\phi)$, $\mathrm{F}_{s,2}(\phi)$ are variations, of constant types, having a period of half a lunation; and all these swell and contract with a wave-like oscillation—$\mathrm{F}_{c,1}(\phi)$, $\mathrm{F}_{s,1}(\phi)$ in the period of a day, and $\mathrm{F}_{c,2}(\phi)$, $\mathrm{F}_{s,2}(\phi)$ in the

each term of which is symbolical of a definite physical conception, viz., that an otherwise constant variation swells and contracts with a wave-like motion, as the age of the moon increases, between the limits $-f(h)$ and $+f(h)$.

13. If the initial new moon occur at h' hours of the initial solar day, from the beginning of which time is reckoned in solar astronomical hours, the age of the moon will become $h-h'$, the period of a lunation 24P; and for $\frac{2\pi}{\mathrm{P}}t$ may be substituted $\frac{2\pi}{24\mathrm{P}}(h-h')$: and if, further, $f(h)$ be expressed in the form

$$a_1 \cos\frac{2\pi}{24}h + b_1 \sin\frac{2\pi}{24}h + a_2 \cos 2\left(\frac{2\pi}{24}h\right) + b_2 \sin 2\left(\frac{2\pi}{24}h\right) + \&c.,$$

our extended formula may easily be transformed into

$$\begin{aligned}
&\mathrm{A}_1 \cos\left\{\frac{2\pi}{24}h\left(1-\frac{1}{\mathrm{P}}\right)+\alpha\right\} + \mathrm{B}_1 \cos\left\{\frac{2\pi}{24}2h\left(1-\frac{1}{2\mathrm{P}}\right)+\beta\right\}\\
&+\mathrm{C}_1 \cos\left\{\frac{2\pi}{24}2h\left(1+\frac{1}{2\mathrm{P}}\right)+\gamma\right\} + \mathrm{D}_1 \cos\left\{\frac{2\pi}{24}h\left(1+\frac{1}{\mathrm{P}}\right)+\delta\right\}\\
&+\mathrm{A}_2 \cos\left\{\frac{2\pi}{24}h\left(1-\frac{2}{\mathrm{P}}\right)+\epsilon\right\} + \mathrm{B}_2 \cos\left\{\frac{2\pi}{24}2h\left(1-\frac{1}{\mathrm{P}}\right)+\zeta\right\}\\
&+\mathrm{C}_2 \cos\left\{\frac{2\pi}{24}2h\left(1+\frac{1}{\mathrm{P}}\right)+\eta\right\} + \mathrm{D}_2 \cos\left\{\frac{2\pi}{24}h\left(1+\frac{2}{\mathrm{P}}\right)+\theta\right\},
\end{aligned}$$

where the numbers A_1, B_1, C_1, D_1, &c., and the angles α, β, γ, δ, &c., are constants; that is to say, it may—inclusive of the first four terms of $f(h)$—be transformed into eight simple waves whose periods, in solar hours, are

$$24\frac{\mathrm{P}}{\mathrm{P}-1};\ 12\frac{2\mathrm{P}}{2\mathrm{P}-1};\ 12\frac{2\mathrm{P}}{2\mathrm{P}+1};\ 24\frac{\mathrm{P}}{\mathrm{P}+1};\ 24\frac{\mathrm{P}}{\mathrm{P}-2};\ 12\frac{\mathrm{P}}{\mathrm{P}-1};\ 12\frac{\mathrm{P}}{\mathrm{P}+1};\ \text{and}\ 24\frac{\mathrm{P}}{\mathrm{P}+2}.$$

Of these periods the first and sixth are the lunar day and half-day respectively; from which it follows that, even if our extended formula be a substantially correct expres-

period of half-a-day. It thus appears that θ and ϕ are reciprocally related, so that the period of either may be regarded as that of the variation of constant type, and the period of the other is then that in which the variation of constant type oscillates, whilst the complex variation of the formula remains identically the same; and this result is general so long as the number of terms in the formula is the same as the number of terms in each of the variations of constant type. The name—the luni-solar variation—has been chosen to distinguish the variation expressed by the formula as one involving the periods of a lunation and the solar day, and of sub-multiples of these periods; and the name—typical variation—has been given to the variations of constant type.

sion of the phenomena in question, there is nothing anomalous in our finding, as we do in fact, definite lunar diurnal variations from the observations of *complete* lunations. It will, indeed, be seen further on (paragraph 17) that the lunar half-day wave is one of the two most prominent, and that the lunar day wave has, generally speaking, an amplitude as great as any of the remaining five.

14. Proceeding now to find the values of $f_{c_1}(h)$, $f_{s_1}(h)$, having entered the observed lunar diurnal variation for new moon in a Table having the solar hours, from 0 to 23, marked at the top of the columns, commencing with 0 hours of the lunar day, we enter underneath this the observed lunar diurnal variation for full moon, commencing with 12 hours, and then subtract the lower entries from the upper; half the difference we take to be the value of $f_{c_1}(h)$ as derived from the new moon and full moon variations. Similarly, entering the observed lunar diurnal variation for first quarter, commencing with 18 hours, and under it the observed lunar diurnal variation for last quarter, commencing with 6 hours, and subtracting the lower numbers and dividing by 2, we obtain the value of $f_{s_1}(h)$ as derived from the first quarter and last quarter variations. In like manner we obtain from the observed lunar diurnal variation for the one-eighth and five-eighths phases the value of $f_{c_1}(h)\cos 45° + f_{s_1}(h)\sin 45°$ or $\frac{1}{\sqrt{2}}\{f_{c_1}(h)+f_{s_1}(h)\} = a$ (say); and from the variations for the three-eighths and seven-eighths phases the value of $\frac{1}{\sqrt{2}}\{-f_{c_1}(h)+f_{s_1}(h)\} = b$ (say): combining the last two quantities, we find $\frac{1}{\sqrt{2}}(a-b) = f_{c_1}$ and $\frac{1}{\sqrt{2}}(a+b) = f_{s_1}$ as values derived from the variations of the eighths phases. In Tables 11 to 18 are collected together the results of these various calculations.

TABLE 11.—Declination.

	Derived from lunar diurnal variations for what phases.	Typical variation.	Bombay									
			0	1	2	3	4	5	6	7	8	9
a	New and full moon . .	$f_{c-1}(h)$	+·000004	+·000003	−·000006	−·000002	·000000	·000000	−·000006	−·000008	−·000006	−·000003
b	First and last quarters .	$f_{s-1}(h)$	+·000001	+·000005	+·000001	+·000007	+·000006	+·000003	+·000003	+·000002	·000000	−·000001
c	One and five-eighths . .	$\frac{1}{\sqrt{2}}\{f_{c-1}(h)+f_{s-1}(h)\}$.	−·000001	+·000005	−·000004	−·000011	−·000001	−·000001	+·000001	−·000003	−·000006	−·000007
d	Three and seven-eighths.	$\frac{V}{\sqrt{2}}\{-f_{c-1}(h)+f_{s-1}(h)\}$	+·000012	+·000005	−·000003	+·000004	−·000003	·000000	+·000001	−·000001	−·000002	+·000001
e	Eighths	$f_{c-1}(h)$	·000000	+·000004	−·000003	−·000003	·000000	−·000001	·000000	−·000002	−·000004	−·000005
f		$f_{s-1}(h)$	+·000008	+·000004	−·000002	+·000003	−·000002	·000000	·000000	·000000	−·000002	·000000
g	Mean of *a* and *e* . . .	$f_{c-1}(h)$	+·000002	+·000003	−·000004	−·000005	·000000	−·000001	−·000003	−·000005	−·000005	−·000004
h	Mean of *b* and *f* . . .	$f_{s-1}(h)$	+·000005	+·000004	·000000	+·000005	+·000002	+·000002	+·000002	+·000001	−·000001	·000000

TABLE 12.—Declination.

	Derived from lunar diurnal variations for what phases.	Typical variation.	Bombay									
			0	1	2	3	4	5	6	7	8	9
a	New and full moon . .	$f_{c-1}(h)$	·000000	·000000	−·000001	−·000003	−·000003	−·000002	−·000001	−·000004	−·000004	−·000002
b	First and last quarters .	$f_{s-1}(h)$	−·000003	−·000001	+·000001	+·000001	·000000	+·000001	·000000	·000000	·000000	·000000
c	One and five-eighths . .	$\frac{1}{\sqrt{2}}\{f_{c-1}(h)+f_{s-1}(h)\}$.	−·000001	−·000003	−·000009	−·000001	−·000001	−·000003	·000000	+·000004	+·000002	+·000002
d	Three and seven-eighths.	$\frac{1}{\sqrt{2}}\{-f_{c-1}(h)+f_{s-1}(h)\}$	−·000005	−·000001	−·000002	+·000005	+·000004	+·000004	+·000005	−·000005	−·000004	−·000003
e	Eighths	$f_{c-1}(h)$	−·000001	−·000002	−·000008	−·000001	·000000	−·000002	·000000	+·000003	+·000001	+·000002
f		$f_{s-1}(h)$	−·000004	−·000001	−·000002	+·000004	+·000003	+·000003	+·000003	−·000004	−·000003	−·000002
g	Mean of *a* and *e* . . .	$f_{c-1}(h)$	−·000001	−·000001	−·000004	−·000002	−·000002	−·000002	·000000	−·000001	−·000001	·000000
h	Mean of *b* and *f* . . .	$f_{s-1}(h)$	−·000003	−·000001	·000000	+·000002	+·000001	+·000002	+·000001	−·000002	−·000001	−·000001

TABLE 13.—Declination.

	Derived from lunar diurnal variations for what phases.	Typical variation.	Bombay									
			0	1	2	3	4	5	6	7	8	9
a	New and full moon . .	$f_{c-1}(h)$	+·000004	−·000001	−·000003	−·000005	−·000005	+·000004	+·000006	+·000003	+·000001	−·000001
b	First and last quarters .	$f_{s-1}(h)$	+·000001	·000000	+·000001	+·000001	+·000003	+·000001	−·000003	−·000002	·000000	+·000002
c	One and five-eighths . .	$\frac{1}{\sqrt{2}}\{f_{c-1}(h)+f_{s-1}(h)\}$.	+·000004	−·000008	−·000010	−·000014	−·000008	−·000005	−·000002	−·000005	−·000001	−·000003
d	Three and seven-eighths.	$\frac{1}{\sqrt{2}}\{-f_{c-1}(h)+f_{s-1}(h)\}$	−·000001	−·000001	+·000013	+·000005	+·000003	·000000	+·000002	−·000001	−·000001	−·000003
e	Eighths	$f_{c-1}(h)$	+·000003	−·000005	−·000007	−·000010	−·000008	−·000003	−·000001	−·000004	·000000	−·000002
f		$f_{s-1}(h)$	−·000001	·000000	+·000009	+·000004	+·000002	·000000	+·000001	−·000001	·000000	−·000002
g	Mean of *a* and *e* . . .	$f_{c-1}(h)$	+·000003	−·000003	−·000005	−·000008	−·000006	·000000	+·000002	·000000	·000000	−·000002
h	Mean of *b* and *f* . . .	$f_{s-1}(h)$	·000000	·000000	+·000005	+·000002	+·000003	·000000	−·000001	−·000001	·000000	·000000

November to January.

Astronomical Hours.

10	11	12	13	14	15	16	17	18	19	20	21	22	23
−·000001	·000000	−·000002	+·000001	+·000001	+·000005	+·000004	+·000002	·000000	+·000001	+·000006	+·000004	−·000005	·000000
·000000	·000000	−·000001	−·000001	−·000003	−·000007	−·000007	−·000003	−·000002	−·000001	−·000002	−·000003	−·000004	+·000003
−·000003	+·000002	−·000001	·000000	+·000004	+·000008	+·000005	+·000002	−·000001	+·000001	+·000002	+·000010	+·000001	+·000006
·000000	·000000	−·000003	+·000001	−·000004	−·000005	−·000007	−·000004	−·000004	−·000001	−·000001	+·000006	+·000006	+·000001
−·000002	+·000002	−·000001	·000000	+·000003	+·000005	+·000004	+·000002	·000000	·000000	+·000002	+·000007	·000000	+·000004
·000000	·000000	−·000002	+·000001	−·000003	−·000003	−·000005	−·000003	−·000003	·000000	−·000001	+·000004	+·000004	+·000001
−·000002	+·000001	−·000001	·000000	+·000002	+·000005	+·000004	+·000002	·000000	+·000001	+·000005	+·000006	−·000001	+·000002
·000000	·000000	−·000002	·000000	−·000003	−·000005	−·000006	−·000003	−·000002	−·000001	−·000002	·000000	+·000001	+·000002

February to April.

Astronomical Hours.

10	11	12	13	14	15	16	17	18	19	20	21	22	23
+·000002	+·000002	+·000007	+·000003	+·000006	+·000009	+·000003	+·000005	+·000002	−·000001	−·000003	−·000002	−·000002	−·000005
−·000004	−·000006	·000000	+·000002	·000000	−·000002	·000000	+·000004	+·000004	+·000001	+·000002	+·000002	+·000006	−·000012
+·000004	+·000004	+·000001	+·000009	+·000007	+·000002	−·000003	−·000003	·000000	−·000005	−·000003	+·000002	−·000002	−·000006
+·000004	−·000006	−·000003	−·000006	−·000005	·000000	−·000005	+·000001	+·000006	+·000007	+·000006	−·000005	+·000003	+·000003
+·000003	+·000003	+·000001	+·000006	+·000005	+·000001	−·000002	−·000002	·000000	−·000003	−·000002	+·000001	−·000002	−·000004
+·000003	−·000004	−·000002	−·000004	−·000004	·000000	−·000003	·000000	+·000004	+·000005	+·000004	−·000003	+·000002	+·000002
+·000003	+·000002	+·000004	+·000005	+·000006	+·000005	+·000001	+·000002	+·000001	−·000002	−·000003	·000000	−·000002	−·000004
·000000	−·000004	−·000001	−·000001	−·000002	−·000001	−·000002	+·000002	+·000004	+·000003	+·000003	−·000001	+·000004	−·000005

May to July.

Astronomical Hours.

10	11	12	13	14	15	16	17	18	19	20	21	22	23
+·000001	−·000001	+·000003	−·000001	−·000001	+·000001	+·000002	+·000001	+·000003	·000000	−·000006	−·000007	+·000004	−·000001
·000000	·000000	−·000001	−·000002	−·000004	−·000006	−·000005	−·000002	−·000002	+·000002	·000000	−·000003	+·000005	+·000006
·000000	+·000006	·000003	+·000001	+·000003	+·000006	+·000002	+·000007	+·000008	−·000003	+·000002	+·000010	+·000001	+·000008
−·000001	−·000006	−·000007	−·000006	−·000006	−·000002	−·000005	−·000005	−·000001	+·000004	−·000003	+·000012	+·000004	+·000002
·000000	+·000004	·000000	·000000	+·000002	+·000004	+·000001	+·000005	+·000005	−·000002	+·000001	+·000007	·000000	+·000006
−·000001	−·000004	−·000005	−·000004	−·000004	−·000001	−·000003	−·000003	·000000	+·000001	−·000002	+·000003	+·000003	+·000002
+·000001	+·000001	+·000002	·000000	·000000	+·000003	+·000002	+·000003	+·000004	−·000001	−·000002	·000000	+·000002	+·000002
−·000001	−·000002	−·000003	−·000003	−·000004	−·000004	−·000004	−·000003	−·000001	+·000003	−·000001	+·000008	+·000004	+·000004

TABLE 14.—Declination.

	Derived from lunar diurnal variations for what phases.	Typical variation.	Bombay									
			0	1	2	3	4	5	6	7	8	9
a	New and full moon	$f_{e-1}(h)$	−·000003	−·000001	−·000003	+·000001	+·000002	·000000	·000000	+·000005	+·000006	+·000001
b	First and last quarters	$f_{e+1}(h)$	−·000001	−·000015	−·000002	·000000	·000000	+·000004	−·000001	·000000	−·000002	·000000
c	One and five-eighths	$\frac{1}{\sqrt{2}}\{f_{e-1}(h)+f_{e+1}(h)\}$	+·000003	+·000009	−·000003	+·000003	·000000	+·000004	+·000004	·000000	+·000001	+·000002
d	Three and seven-eighths	$\frac{1}{\sqrt{2}}\{-f_{e-1}(h)+f_{e+1}(h)\}$	−·000004	−·000002	−·000003	−·000003	+·000004	+·000009	+·000007	+·000003	+·000003	−·000002
e	Eighths	$f_{e-1}(h)$	+·000002	+·000006	−·000002	+·000005	·000000	+·000003	+·000003	·000000	+·000001	+·000002
f	Eighths	$f_{e+1}(h)$	−·000003	−·000002	−·000002	−·000002	−·000003	+·000006	+·000005	+·000002	+·000002	−·000002
g	Mean of *a* and *e*	$f_{e-1}(h)$	·000000	+·000002	−·000003	+·000003	+·000001	+·000001	+·000002	+·000003	+·000003	+·000002
h	Mean of *b* and *f*	$f_{e+1}(h)$	−·000002	−·000009	−·000002	−·000001	−·000001	+·000005	+·000002	+·000001	·000000	−·000001

TABLE 15.—Horizontal Force.

	Derived from lunar diurnal variations for what phases.	Typical variation.	Bombay									
			0	1	2	3	4	5	6	7	8	9
a	New and full moon	$f_{e-1}(h)$	·000000	−·000004	−·000004	−·000003	−·000003	−·000003	·000000	·000000	·000000	+·000004
b	First and last quarters	$f_{e+1}(h)$	−·000014	−·000021	−·000009	−·000008	−·000005	·000000	·000000	+·000003	+·000005	+·000003
c	One and five-eighths	$\frac{1}{\sqrt{2}}\{f_{e-1}(h)+f_{e+1}(h)\}$	−·000014	−·000004	+·000006	+·000003	−·000009	+·000009	+·000011	+·000015	+·000009	+·000011
d	Three and seven-eighths	$\frac{1}{\sqrt{2}}\{-f_{e-1}(h)+f_{e+1}(h)\}$	·000000	·000000	−·000003	−·000004	−·000007	−·000002	−·000003	+·000005	+·000006	−·000001
e	Eighths	$f_{e-1}(h)$	−·000010	−·000003	+·000004	+·000002	−·000006	+·000006	+·000008	+·000011	+·000006	+·000008
f	Eighths	$f_{e+1}(h)$	·000000	·000000	−·000005	−·000003	−·000005	−·000001	−·000002	+·000004	+·000004	−·000001
g	Mean of *a* and *e*	$f_{e-1}(h)$	−·000005	−·000003	·000000	·000000	−·000005	+·000001	+·000004	+·000006	+·000003	+·000006
h	Mean of *b* and *f*	$f_{e+1}(h)$	−·000007	−·000010	−·000007	−·000005	−·000005	−·000001	−·000001	+·000003	+·000004	+·000001

TABLE 16.—Horizontal Force.

	Derived from lunar diurnal variations for what phases.	Typical variation.	Bombay									
			0	1	2	3	4	5	6	7	8	9
a	New and full moon	$f_{e-1}(h)$	−·000004	−·000002	+·000001	−·000004	−·000007	−·000004	+·000001	+·000003	+·000005	−·000001
b	First and last quarters	$f_{e+1}(h)$	−·000004	·000000	+·000007	+·000014	+·000010	+·000006	+·000005	+·000004	·000000	·000000
c	One and five-eighths	$\frac{1}{\sqrt{2}}\{f_{e-1}(h)+f_{e+1}(h)\}$	+·000011	−·000008	−·000019	−·000012	·000000	+·000006	·000000	−·000008	−·000008	+·000003
d	Three and seven-eighths	$\frac{1}{\sqrt{2}}\{-f_{e-1}(h)+f_{e+1}(h)\}$	+·000007	+·000007	+·000008	−·000008	−·000012	−·000008	−·000004	−·000004	+·000005	−·000010
e	Eighths	$f_{e-1}(h)$	+·000008	−·000005	−·000013	−·000008	·000000	+·000004	·000000	−·000006	−·000005	+·000002
f	Eighths	$f_{e+1}(h)$	+·000005	+·000005	+·000005	−·000005	−·000008	−·000006	−·000003	−·000003	+·000003	−·000007
g	Mean of *a* and *e*	$f_{e-1}(h)$	+·000002	−·000004	−·000006	−·000006	−·000003	·000000	·000000	−·000001	·000000	·000000
h	Mean of *b* and *f*	$f_{e+1}(h)$	·000000	+·000003	+·000006	+·000004	+·000001	·000000	+·000001	+·000001	+·000001	−·000004

August to October.

Astronomical Hours.

10	11	12	13	14	15	16	17	18	19	20	21	22	23
+·000002	·000000	−·000002	·000000	−·000001	−·000002	+·000001	·000000	−·000002	·000000	·000000	−·000005	−·000006	+·000001
+·000003	−·000001	−·000001	·000000	−·000003	·000000	·000000	−·000001	·000000	+·000003	+·000006	+·000007	+·000009	·000000
−·000002	−·000004	·000000	·000000	−·000001	−·000002	−·000003	−·000005	·000000	−·000002	−·000007	−·000005	−·000002	−·000004
−·000001	+·000002	−·000001	·000000	−·000003	+·000002	+·000003	+·000002	−·000003	−·000002	+·000001	+·000002	−·000005	·000000
−·000001	−·000003	·000000	·000000	−·000001	−·000001	−·000002	−·000003	·000000	−·000001	−·000005	−·000004	−·000002	−·000003
·000000	+·000002	−·000001	·000000	−·000002	+·000001	+·000002	+·000001	−·000002	−·000001	+·000001	+·000002	−·000004	·000000
·000000	−·000001	−·000001	·000000	−·000001	−·000002	·000000	−·000002	−·000001	−·000001	−·000002	−·000004	−·000004	−·000001
+·000001	·000000	−·000001	·000000	−·000003	·000000	+·000001	·000000	−·000001	+·000001	+·000004	+·000005	+·000003	·000000

November to January.

Astronomical Hours.

10	11	12	13	14	15	16	17	18	19	20	21	22	23
·000000	−·000004	−·000003	−·000005	·000000	+·000002	+·000001	+·000002	+·000005	+·000007	+·000002	+·000003	−·000001	+·000004
+·000009	+·000010	·000000	+·000005	+·000003	+·000005	+·000003	+·000013	+·000007	+·000001	+·000001	−·000003	·000000	−·000007
+·000008	+·000004	−·000002	+·000005	+·000004	−·000006	−·000009	−·000007	+·000002	−·000003	−·000012	−·000005	−·000009	−·000016
−·000001	·000000	+·000011	−·000003	·000000	+·000005	+·000004	+·000006	+·000006	+·000008	−·000003	−·000001	−·000008	+·000004
+·000006	+·000003	−·000001	+·000003	+·000003	−·000004	−·000006	−·000005	+·000002	−·000002	−·000008	−·000004	−·000006	−·000011
−·000001	·000000	+·000008	−·000002	·000000	+·000003	+·000003	+·000004	+·000004	+·000005	−·000002	−·000001	−·000005	+·000003
+·000003	·000000	−·000002	−·000001	+·000001	−·000001	−·000003	−·000001	+·000004	+·000002	−·000003	·000000	−·000004	−·000004
+·000004	+·000005	+·000004	+·000002	+·000002	+·000004	+·000005	+·000008	+·000006	+·000003	·000000	−·000002	−·000002	−·000002

February to April.

Astronomical Hours.

10	11	12	13	14	15	16	17	18	19	20	21	22	23
+·000003	·000000	+·000006	+·000005	+·000003	+·000003	−·000003	·000000	−·000001	−·000001	+·000001	+·000001	−·000002	+·000003
−·000002	−·000001	−·000001	−·000005	−·000007	−·000004	+·000001	+·000004	+·000002	−·000004	−·000003	−·000014	−·000009	−·000006
+·000013	+·000015	+·000018	+·000003	−·000001	+·000009	+·000003	−·000011	·000000	−·000003	−·000009	−·000003	−·000014	+·000001
−·000011	−·000008	−·000004	+·000002	+·000002	+·000007	+·000003	+·000008	·000000	+·000003	+·000006	+·000008	+·000002	+·000005
+·000009	+·000011	+·000013	+·000002	−·000007	+·000006	+·000002	·000000	·000000	−·000002	−·000006	−·000002	−·000010	·000000
−·000008	−·000006	−·000003	+·000002	+·000002	+·000005	+·000002	+·000005	·000000	+·000002	+·000004	+·000005	+·000001	+·000003
+·000006	+·000006	+·000009	+·000004	+·000001	+·000003	·000000	·000000	−·000001	−·000002	−·000003	·000000	−·000006	+·000002
−·000005	−·000004	−·000002	−·000002	−·000002	·000000	+·000002	+·000005	+·000001	−·000001	·000000	−·000004	−·000004	−·000001

TABLE 17.—Horizontal Force.

Bombay

	Derived from lunar diurnal variations for what phases.	Typical variation.	0	1	2	3	4	5	6	7	8	9
a	New and full moon	$f_{\sigma,1}(h)$	−·000007	−·000006	−·000001	−·000003	−·000003	·000000	+·000003	+·000002	·000000	+·000003
b	First and last quarters	$f_{\sigma,1}(h)$	·000000	+·000005	+·000001	+·000005	+·000009	·000000	·000000	+·000002	−·000006	−·000004
c	One and five-eighths	$\frac{1}{\sqrt{2}}\{f_{\sigma,1}(h)+f_{\sigma,1}(h)\}$	+·000004	+·000003	+·000009	+·000005	+·000004	+·000004	−·000004	·000000	−·000005	−·000001
d	Three and seven-eighths	$\frac{1}{\sqrt{2}}\{-f_{\sigma,1}(h)+f_{\sigma,1}(h)\}$	+·000021	+·000008	+·000008	+·000016	+·000008	+·000006	+·000002	·000000	·000000	−·000008
e, *f*	Eighths	$f_{\sigma,1}(h)$	+·000003	+·000002	+·000006	+·000004	+·000003	+·000003	−·000003	·000000	−·000003	·000000
		$f_{\sigma,1}(h)$	+·000015	+·000006	+·000006	+·000011	+·000006	+·000004	+·000001	·000000	·000000	−·000005
g	Mean of *a* and *e*	$f_{\sigma,1}(h)$	−·000002	−·000002	+·000003	·000000	·000000	+·000002	·000000	+·000001	−·000002	+·000001
h	Mean of *b* and *f*	$f_{\sigma,1}(h)$	+·000008	+·000005	+·000003	+·000008	+·000007	+·000002	+·000001	+·000001	−·000003	−·000005

TABLE 18.—Horizontal Force.

Bombay

	Derived from lunar diurnal variations for what phases.	Typical variation.	0	1	2	3	4	5	6	7	8	9
a	New and full moon	$f_{\sigma,1}(h)$	−·000002	·000000	·000000	−·000004	−·000004	+·000001	·000000	−·000004	−·000002	+·000003
b	First and last quarters	$f_{\sigma,1}(h)$	+·000012	+·000012	·000000	+·000003	+·000012	+·000001	−·000002	+·000001	−·000003	−·000006
c	One and five-eighths	$\frac{1}{\sqrt{2}}\{f_{\sigma,1}(h)+f_{\sigma,1}(h)\}$	−·000001	−·000004	+·000005	−·000016	−·000015	−·000014	·000000	+·000002	+·000005	−·000003
d	Three and seven-eighths	$\frac{1}{\sqrt{2}}\{-f_{\sigma,1}(h)+f_{s,1}(h)\}$	−·000005	+·000001	+·000013	−·000005	−·000013	−·000006	−·000012	−·000006	−·000008	−·000008
e, *f*	Eighths	$f_{\sigma,1}(h)$	·000000	−·000003	+·000003	−·000011	−·000011	−·000010	·000000	+·000001	+·000004	−·000002
		$f_{\sigma,1}(h)$	−·000003	+·000001	+·000009	−·000004	−·000009	−·000004	−·000008	−·000004	−·000006	−·000005
g	Mean of *a* and *e*	$f_{\sigma,1}(h)$	−·000001	−·000001	+·000002	−·000008	−·000008	−·000004	·000000	−·000001	+·000001	·000000
h	Mean of *b* and *f*	$f_{\sigma,1}(h)$	+·000004	+·000007	+·000004	·000000	+·000001	−·000001	−·000005	−·000001	−·000004	−·000006

May to July.

Astronomical Hours.

10	11	12	13	14	15	16	17	18	19	20	21	22	23
−·000002	+·000001	+·000001	+·000003	+·000004	+·000004	+·000002	+·000005	+·000005	+·000003	−·000001	−·000004	−·000005	−·000002
−·000003	−·000001	+·000004	+·000002	−·000001	+·000001	+·000002	+·000001	+·000005	+·000002	−·000004	−·000013	·000000	−·000010
+·000002	−·000002	+·000003	+·000004	+·000005	·000000	+·000007	+·000006	·000000	·000000	−·000007	−·000007	−·000013	−·000006
−·000004	−·000004	−·000006	−·000008	·000000	−·000008	−·000007	−·000017	−·000016	−·000008	−·000019	+·000003	+·000007	+·000011
+·000001	−·000002	+·000002	+·000008	+·000004	·000000	+·000005	+·000004	·000000	·000000	−·000005	−·000005	−·000009	−·000004
−·000003	−·000003	−·000004	−·000005	·000000	−·000005	−·000005	−·000012	−·000011	−·000006	−·000007	+·000002	+·000005	+·000003
·000000	·000000	+·000002	+·000003	+·000004	+·000002	+·000004	+·000005	+·000003	+·000001	−·000003	−·000005	−·000007	−·000002
−·000003	−·000002	·000000	−·000002	−·000001	−·000002	−·000001	−·000005	−·000003	−·000002	−·000006	−·000005	+·000002	−·000001

August to October.

Astronomical Hours.

10	11	12	13	14	15	16	17	18	19	20	21	22	23
·000000	+·000004	+·000005	·000000	+·000006	+·000003	+·000001	+·000001	+·000005	+·000002	−·000032	−·000001	−·000005	−·000005
−·000007	−·000008	−·000009	−·000009	+·000001	−·000003	−·000005	−·000009	−·000002	+·000001	−·000003	+·000005	+·000007	+·000009
+·000007	+·000010	+·000008	+·000007	+·000006	+·000002	·000000	+·000002	+·000001	·000000	−·000007	+·000005	+·000005	−·000001
+·000004	·000000	+·000007	+·000001	+·000001	+·000007	+·000005	+·000007	+·000008	+·000008	+·000007	+·000006	−·000008	−·000007
+·000005	+·000007	+·000006	+·000005	+·000004	+·000001	·000000	+·000001	·000000	·000000	−·000005	+·000004	+·000004	−·000001
+·000003	·000000	+·000005	·000000	+·000001	+·000005	+·000004	+·000005	+·000005	+·000006	+·000005	+·000004	−·000006	−·000005
+·000003	+·000001	+·000006	+·000003	+·000005	+·000002	·000000	+·000001	+·000003	+·000001	−·000004	+·000001	·000000	−·000003
−·000002	−·000004	−·000002	−·000004	+·000001	+·000001	·000000	−·000002	+·000001	+·000004	+·000001	+·000005	+·000001	+·000002

The mean variations $f_{c,1}(h)$, $f_{s,1}(h)$ (lines g and h of Tables 11 to 18), are curved in order in figs. 22 to 37.

15. Extending now the process of elimination described in paragraph 11, so as to further clear the observed variations of their elements $f_{c,1}(h)$, $f_{s,1}(h)$, &c., as shown on lines a and b of Tables 11 to 18, we subtract $f_{c,1}(h)$ from the observed lunar diurnal variation at new moon, commencing with 0 hours; subtract $f_{s,1}(h)$ from the observed variation at first quarter, commencing with 6 hours; add $f_{c,1}(h)$ to the observed variation at full moon, commencing with 12 hours; and add $f_{s,1}(h)$ to the observed variation at last quarter, commencing with 18 hours; thus reducing the residuals formerly obtained to four new residuals, the mean of which may be taken as the residual lunar diurnal variation for the quarters of the moon. A similar process, using lines c and d of Tables 11 to 18, in lieu of lines a and b, leads to the residual lunar diurnal variation for the eighths phases. These residuals, for each quarter of the year and for both the magnetic elements, were found to be practically insignificant, the hourly numbers in all of them lying between the limits $\pm$·000002. From this we conclude that, in each quarter of the year and for each magnetic element separately, our extended formula practically embodies the whole of the observed lunar diurnal variation for the full lunation.

16. Coefficients of the harmonic equivalents of the typical variations, expressed in the form

$$a_1 \cos \frac{2\pi}{24}h + b_1 \sin \frac{2\pi}{24}h + a_2 \cos 2\left(\frac{2\pi}{24}h\right) + b_2 \sin 2\left(\frac{2\pi}{24}h\right) + \&c.,$$

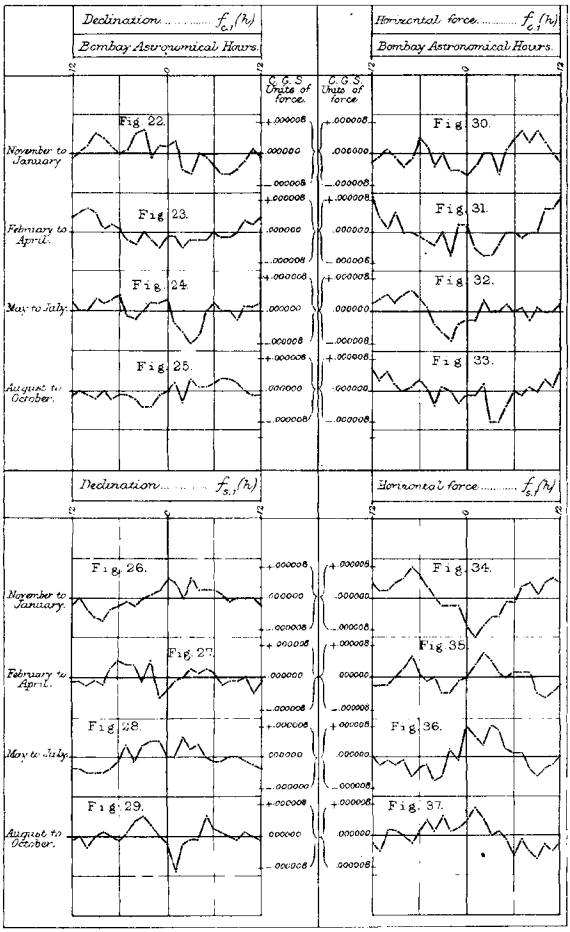
were calculated for each case, the data being taken from Tables 9 and 10, and from lines g and h of Tables 11 to 18, and their values are exhibited in Tables 19 and 20.

TABLE 19.

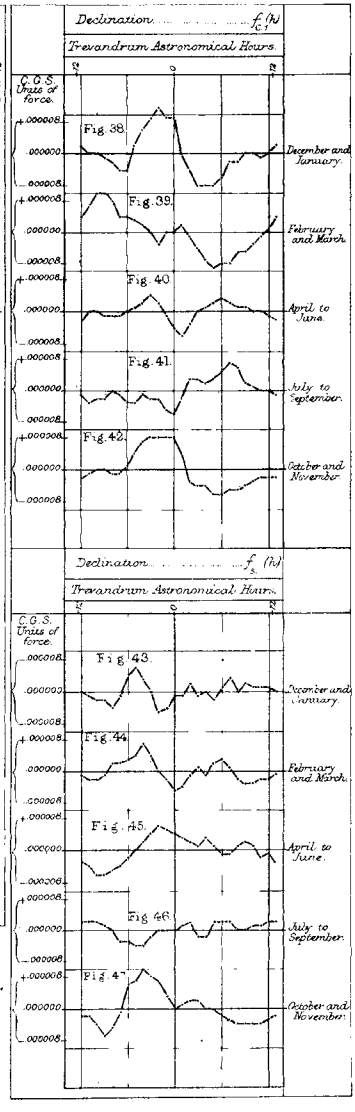
Declination.		a_1	b_1	a_2	b_2	A_1	B_1	A_2	B_2
November to January	$f_{c,1}(h)$	+·0000005	−·0000034	+·0000006	+·0000004				
	$f_{s,1}(h)$	...	...	...	...	+·0000023	+·0000023	+·0000010	−·0000003
	$f_{c,2}(h)$	+·0000031	+·0000026	+·0000097	+·0000040				
	$f_{s,2}(h)$	...	...	...	...	−·0000030	+·0000031	−·0000055	+·0000077
February to April	$f_{c,1}(h)$	−·0000032	−·0000010	+·0000009	+·0000009				
	$f_{s,1}(h)$	...	...	...	...	+·0000008	−·0000006	−·0000010	·0000000
	$f_{c,2}(h)$	+·0000014	−·0000022	+·0000023	−·0000009				
	$f_{s,2}(h)$	...	...	...	...	−·0000014	−·0000001	−·0000002	+·0000016
May to July	$f_{c,1}(h)$	−·0000014	−·0000019	−·0000001	−·0000011				
	$f_{s,1}(h)$	...	...	...	...	+·0000029	+·0000008	+·0000002	−·0000010
	$f_{c,2}(h)$	−·0000043	·0000000	−·0000078	+·0000013				
	$f_{s,2}(h)$	...	...	...	...	−·0000024	−·0000049	−·0000017	−·0000030
August to October	$f_{c,1}(h)$	−·0000004	+·0000020	−·0000007	+·0000003				
	$f_{s,1}(h)$	...	...	...	...	−·0000001	−·0000004	−·0000017	−·0000016
	$f_{c,2}(h)$	−·0000054	+·0000008	−·0000076	+·0000047				
	$f_{s,2}(h)$	...	...	...	...	−·0000016	−·0000040	−·0000050	−·0000048

Colaba Observatory, Bombay.

Typical variations of declination and horizontal force at Bombay.



Typical variations of declination at Trevandrum.



West, Newman & Co. lith.

TABLE 20.

Horizontal Force.		a_1	b_1	a_2	b_2	A_1	B_1	A_2	B_2
November to January	$f_{c\cdot1}(h)$	−·0000020	+·0000015	−·0000021	−·0000013				
	$f_{s\cdot1}(h)$	...	...	...	...	−·0000050	−·0000023	−·0000023	−·0000012
	$f_{c\cdot2}(h)$	+·0000006	−·0000093	+·0000001	−·0000126				
	$f_{s\cdot2}(h)$	...	...	...	...	+·0000136	−·0000017	+·0000134	+·0000007
February to April	$f_{c\cdot1}(h)$	−·0000038	−·0000004	+·0000018	−·0000006				
	$f_{s\cdot1}(h)$	...	...	...	...	+·0000015	+·0000003	−·0000014	+·0000025
	$f_{c\cdot2}(h)$	+·0000014	−·0000036	+·0000011	−·0000067				
	$f_{s\cdot2}(h)$	...	...	...	...	+·0000123	+·0000018	+·0000071	+·0000010
May to July	$f_{c\cdot1}(h)$	−·0000023	−·0000003	−·0000010	+·0000025				
	$f_{s\cdot1}(h)$	...	...	...	...	+·0000028	+·0000026	+·0000013	+·0000028
	$f_{c\cdot2}(h)$	−·0000021	−·0000032	−·0000014	−·0000021				
	$f_{s\cdot2}(h)$	...	...	...	...	+·0000053	+·0000017	+·0000044	+·0000007
August to October	$f_{c\cdot1}(h)$	−·0000028	−·0000017	+·0000013	−·0000006				
	$f_{s\cdot1}(h)$	...	...	...	...	+·0000033	−·0000017	+·0000008	+·0000008
	$f_{c\cdot2}(h)$	−·0000004	−·0000037	−·0000003	−·0000033				
	$f_{s\cdot2}(h)$	...	...	...	...	+·0000067	−·0000013	+·0000063	+·0000010

And from these coefficients were calculated the values of $\frac{1}{2}\sqrt{(a_1+B_1)^2+(b_1-A_1)^2}$; $\frac{1}{2}\sqrt{(a_2+B_2)^2+(b_2-A_2)^2}$; $\frac{1}{2}\sqrt{(a_2-B_2)^2+(b_2+A_2)^2}$; and $\frac{1}{2}\sqrt{(a_1-B_1)^2+(b_1+A_1)^2}$ for each pair of typical variations $f_c(h), f_s(h)$. These quantities are the coefficients A, B, C, D, respectively, of our transformed formula in paragraph 13; and their values are entered in Tables 21 and 22.

TABLE 21.

Declination.	A_1	B_1	C_1	D_1	A_2	B_2	C_2	D_2
November to January	·0000031	·0000003	·0000008	·0000010	·0000042	·0000099	·0000012	·0000002
February to April	·0000021	·0000010	·0000004	·0000013	·0000007	·0000019	·0000006	·0000019
May to July	·0000024	·0000008	·0000006	·0000012	·0000048	·0000080	·0000002	·0000012
August to October	·0000011	·0000015	·0000008	·0000009	·0000049	·0000078	·0000014	·0000008

TABLE 22.

Horizontal force.	A_1	B_1	C_1	D_1	A_2	B_2	C_2	D_2
November to January	·0000038	·0000017	·0000018	·0000017	·0000114	·0000130	·0000054	·0000024
February to April	·0000019	·0000021	·0000010	·0000021	·0000081	·0000070	·0000002	·0000043
May to July	·0000015	·0000011	·0000027	·0000027	·0000042	·0000032	·0000015	·0000021
August to October	·0000033	·0000012	·0000002	·0000009	·0000053	·0000048	·0000016	·0000016

17. Regarding these numbers as the amplitudes of the eight simple waves whose periods are specified in paragraph 13, we see that generally B_2, and in a less degree A_1—which refer to the lunar half-day and the lunar day respectively—form important elements of the whole luni-solar variation; and scarcely less important are the elements that have the A_2's for their amplitudes: the numbers for the remaining five periods are generally smaller, though for none of them are they so small as to approach general insignificance.

18. Up to this point we have, in comparing our formula with observation, had to adapt to the purpose variations obtained for the period of the lunar day. It would obviously be a more direct procedure to arrange the so-called lunar differences of a given season in solar days, according to the age of the moon, and, although the labour of copying out the numbers so arranged, and of re-computing, is considerable, we have thought the verification of the results obtained by the indirect mode of procedure of sufficient importance to justify the undertaking of the task, at least in respect of the element of declination, and for that season, November to January, when the luni-solar variations at Bombay have the largest range. Accordingly, abstract sheets were prepared for the 1st, 2nd, 3rd, &c., solar days after new moon, embracing all such days in the months November to January of the years 1846 to 1870. The hourly sums and means and the diurnal variations were then taken on each abstract sheet, with the results shown in Table 23.

TABLE 23.—Luni-solar Variations of Declination for each Solar Day after New Moon in the Quarter November to January, expressed in C.G.S. Units of Force.

Bombay astronomical hours.		Days after new moon.														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
h.	m.															
12	12	+ 0·0000045	+ 0·0000028	+ 0·0000091	− 0·0000072	− 0·0000036	− 0·0000007	− 0·0000054	− 0·0000019	+ 0·0000013	+ 0·0000029	+ 0·0000010	+ 0·0000011	+ 0·0000081	+ 0·0000113	+ 0·0000086
13	12	+ 0·0000010	+ 0·0000028	+ 0·0000052	− 0·0000002	− 0·0000023	− 0·0000071	− 0·0000042	+ 0·0000060	− 0·0000019	− 0·0000125	+ 0·0000013	− 0·0000009	− 0·0000029	+ 0·0000076	− 0·0000005
14	12	− 0·0000007	+ 0·0000064	+ 0·0000079	+ 0·0000112	− 0·0000004	− 0·0000080	− 0·0000027	− 0·0000054	+ 0·0000027	− 0·0000094	− 0·0000086	0·0000000	− 0·0000124	+ 0·0000041	0·0000000
15	12	+ 0·0000017	− 0·0000012	+ 0·0000093	+ 0·0000130	+ 0·0000083	− 0·0000012	− 0·0000028	− 0·0000085	− 0·0000013	− 0·0000108	− 0·0000056	− 0·0000018	− 0·0000101	− 0·0000006	− 0·0000077
16	12	+ 0·0000051	+ 0·0000010	+ 0·0000065	+ 0·0000144	+ 0·0000027	+ 0·0000038	+ 0·0000013	− 0·0000075	− 0·0000035	− 0·0000096	− 0·0000059	− 0·0000037	− 0·0000142	− 0·0000043	− 0·0000461
17	12	− 0·0000068	− 0·0000092	+ 0·0000067	+ 0·0000064	+ 0·0000011	+ 0·0000015	+ 0·0000070	+ 0·0000025	+ 0·0000028	+ 0·0000028	− 0·0000060	− 0·0000044	− 0·0000159	− 0·0000069	− 0·0000219
18	12	− 0·0000101	− 0·0000126	− 0·0000027	+ 0·0000056	+ 0·0000097	+ 0·0000069	+ 0·0000039	+ 0·0000049	+ 0·0000071	+ 0·0000070	− 0·0000014	− 0·0000033	− 0·0000157	− 0·0000163	− 0·0000229
19	12	− 0·0000122	− 0·0000219	+ 0·0000041	+ 0·0000067	− 0·0000002	+ 0·0000159	+ 0·0000191	+ 0·0000040	+ 0·0000077	+ 0·0000148	− 0·0000020	− 0·0000005	− 0·0000130	− 0·0000158	− 0·0000295
20	12	− 0·0000029	− 0·0000101	− 0·0000017	− 0·0000087	+ 0·0000059	+ 0·0000110	+ 0·0000128	+ 0·0000066	− 0·0000029	+ 0·0000118	− 0·0000010	+ 0·0000062	− 0·0000041	− 0·0000252	− 0·0000244
21	12	− 0·0000002	− 0·0000020	− 0·0000145	− 0·0000100	+ 0·0000007	+ 0·0000060	+ 0·0000034	− 0·0000052	− 0·0000044	+ 0·0000023	+ 0·0000003	+ 0·0000068	+ 0·0000063	− 0·0000170	− 0·0000206
22	12	+ 0·0000117	− 0·0000082	− 0·0000126	− 0·0000162	− 0·0000135	− 0·0000015	− 0·0000040	− 0·0000125	+ 0·0000016	− 0·0000031	+ 0·0000074	+ 0·0000167	+ 0·0000234	− 0·0000176	+ 0·0000028
23	12	+ 0·0000091	− 0·0000019	− 0·0000263	− 0·0000050	− 0·0000157	− 0·0000148	− 0·0000093	− 0·0000060	− 0·0000032	− 0·0000004	+ 0·0000075	+ 0·0000059	+ 0·0000211	− 0·0000031	+ 0·0000171
0	12	+ 0·0000163	− 0·0000046	− 0·0000071	− 0·0000156	− 0·0000030	− 0·0000079	− 0·0000139	− 0·0000033	− 0·0000059	− 0·0000005	+ 0·0000114	− 0·0000016	+ 0·0000218	+ 0·0000076	+ 0·0000133
1	12	+ 0·0000283	+ 0·0000191	− 0·0000016	+ 0·0000078	+ 0·0000029	− 0·0000109	− 0·0000164	− 0·0000148	− 0·0000104	− 0·0000132	+ 0·0000011	+ 0·0000014	+ 0·0000209	+ 0·0000160	+ 0·0000221
2	12	+ 0·0000177	+ 0·0000285	+ 0·0000062	+ 0·0000064	− 0·0000051	− 0·0000127	− 0·0000025	− 0·0000194	− 0·0000113	− 0·0000202	+ 0·0000014	+ 0·0000070	+ 0·0000026	+ 0·0000187	+ 0·0000276
3	12	+ 0·0000140	+ 0·0000290	+ 0·0000147	+ 0·0000043	+ 0·0000118	+ 0·0000058	+ 0·0000038	− 0·0000071	− 0·0000179	− 0·0000248	− 0·0000110	− 0·0000121	− 0·0000059	+ 0·0000071	+ 0·0000113
4	12	− 0·0000163	+ 0·0000079	+ 0·0000155	+ 0·0000133	+ 0·0000148	+ 0·0000238	+ 0·0000093	+ 0·0000117	− 0·0000094	+ 0·0000014	− 0·0000164	− 0·0000135	− 0·0000239	− 0·0000012	− 0·0000151
5	12	− 0·0000165	− 0·0000129	− 0·0000036	+ 0·0000099	+ 0·0000082	+ 0·0000125	+ 0·0000134	+ 0·0000112	+ 0·0000087	+ 0·0000131	+ 0·0000019	− 0·0000111	− 0·0000214	− 0·0000130	− 0·0000099
6	12	− 0·0000135	− 0·0000070	− 0·0000112	+ 0·0000033	− 0·0000021	+ 0·0000032	− 0·0000001	+ 0·0000161	+ 0·0000114	+ 0·0000138	+ 0·0000016	− 0·0000035	+ 0·0000004	+ 0·0000093	+ 0·0000068
7	12	− 0·0000100	− 0·0000071	− 0·0000043	− 0·0000027	− 0·0000064	− 0·0000011	+ 0·0000019	+ 0·0000112	+ 0·0000065	+ 0·0000143	+ 0·0000031	− 0·0000022	+ 0·0000031	+ 0·0000045	+ 0·0000157
8	12	− 0·0000129	− 0·0000059	− 0·0000046	− 0·0000126	− 0·0000022	− 0·0000041	− 0·0000064	+ 0·0000059	+ 0·0000107	+ 0·0000038	+ 0·0000106	+ 0·0000019	+ 0·0000133	+ 0·0000141	+ 0·0000061
9	12	− 0·0000031	+ 0·0000027	− 0·0000049	− 0·0000108	− 0·0000043	− 0·0000063	− 0·0000050	+ 0·0000023	+ 0·0000027	+ 0·0000102	+ 0·0000010	+ 0·0000080	+ 0·0000035	+ 0·0000087	+ 0·0000062
10	12	− 0·0000032	+ 0·0000019	+ 0·0000015	− 0·0000069	− 0·0000062	− 0·0000054	− 0·0000005	+ 0·0000083	+ 0·0000046	+ 0·0000050	− 0·0000015	+ 0·0000047	+ 0·0000093	+ 0·0000057	+ 0·0000100
11	12	+ 0·0000049	+ 0·0000033	+ 0·0000022	− 0·0000063	− 0·0000033	− 0·0000062	− 0·0000019	+ 0·0000005	+ 0·0000047	− 0·0000047	+ 0·0000066	− 0·0000008	+ 0·0000063	+ 0·0000055	+ 0·0000113

TABLE 23—continued.

Bombay astronomical hours.		Days after new moon.														
		16	17	18	19	20	21	−9	−8	−7	−6	−5	−4	−3	−2	−1
h.	m.															
12	12	+ 0000077	− 0000029	− 0000001	− 0000017	− 0000014	− 0000056	+ 0000018	− 0000060	− 0000064	+ 0000014	− 0000097	+ 0000070	− 0000010	+ 0000016	+ 0000060
13	12	+ 0000108	− 0000052	+ 0000006	− 0000021	− 0000048	− 0000051	− 0000004	− 0000023	− 0000095	− 0000013	− 0000060	+ 0000050	− 0000039	+ 0000060	+ 0000111
14	12	+ 0000072	− 0000033	+ 0000052	− 0000025	− 0000005	+ 0000062	+ 0000013	− 0000016	− 0000077	+ 0000072	− 0000034	+ 0000026	− 0000063	− 0000012	+ 0000101
15	12	− 0000015	− 0000068	+ 0000098	+ 0000071	+ 0000108	+ 0000029	+ 0000086	+ 0000061	− 0000056	+ 0000037	− 0000076	+ 0000005	+ 0000023	− 0000009	+ 0000031
16	12	− 0000100	− 0000063	+ 0000118	+ 0000081	+ 0000059	+ 0000067	+ 0000068	+ 0000002	+ 0000010	+ 0000019	− 0000013	+ 0000044	− 0000074	− 0000000	+ 0000037
17	12	− 0000061	− 0000064	+ 0000056	+ 0000116	+ 0000091	+ 0000096	+ 0000042	+ 0000045	+ 0000037	+ 0000036	− 0000005	− 0000034	− 0000051	− 0000035	+ 0000022
18	12	− 0000161	− 0000116	+ 0000006	+ 0000058	+ 0000112	+ 0000019	+ 0000021	+ 0000103	+ 0000067	+ 0000123	+ 0000109	− 0000015	+ 0000006	+ 0000013	− 0000126
19	12	− 0000171	− 0000133	− 0000146	+ 0000038	+ 0000103	+ 0000177	+ 0000013	+ 0000194	+ 0000082	+ 0000163	+ 0000048	+ 0000035	− 0000033	− 0000053	− 0000289
20	12	− 0000053	− 0000085	− 0000191	− 0000010	− 0000033	+ 0000193	+ 0000027	+ 0000080	+ 0000132	+ 0000187	+ 0000055	+ 0000020	+ 0000035	− 0000051	− 0000196
21	12	− 0000141	− 0000133	− 0000204	− 0000069	+ 0000004	+ 0000095	+ 0000014	− 0000019	+ 0000214	+ 0000157	+ 0000155	+ 0000243	+ 0000164	− 0000044	+ 0000036
22	12	− 0000003	− 0000087	− 0000194	− 0000164	− 0000143	− 0000068	− 0000004	− 0000027	+ 0000202	+ 0000147	+ 0000234	+ 0000151	+ 0000236	+ 0000007	− 0000081
23	12	+ 0000020	+ 0000048	− 0000167	− 0000192	− 0000009	− 0000141	+ 0000002	− 0000068	+ 0000082	− 0000125	+ 0000180	+ 0000081	+ 0000191	+ 0000109	+ 0000117
0	12	+ 0000004	+ 0000028	− 0000108	− 0000112	− 0000132	− 0000215	− 0000043	− 0000096	− 0000061	− 0000171	+ 0000070	+ 0000033	+ 0000258	+ 0000176	+ 0000181
1	12	+ 0000043	+ 0000282	− 0000085	− 0000106	− 0000056	− 0000218	− 0000291	+ 0000010	− 0000116	− 0000253	+ 0000014	− 0000053	+ 0000247	+ 0000117	+ 0000274
2	12	+ 0000158	+ 0000387	+ 0000158	+ 0000083	+ 0000017	− 0000192	− 0000176	− 0000216	− 0000135	− 0000230	− 0000128	− 0000085	+ 0000023	− 0000072	+ 0000211
3	12	+ 0000146	+ 0000247	+ 0000232	+ 0000198	+ 0000020	− 0000086	− 0000108	− 0000159	− 0000133	− 0000132	− 0000141	− 0000273	− 0000074	− 0000022	+ 0000087
4	12	+ 0000053	+ 0000075	+ 0000212	+ 0000130	+ 0000142	+ 0000211	+ 0000056	+ 0000129	− 0000108	− 0000211	− 0000063	− 0000237	− 0000238	− 0000104	− 0000092
5	12	− 0000130	− 0000062	+ 0000094	+ 0000091	+ 0000160	+ 0000190	+ 0000100	+ 0000146	+ 0000022	− 0000007	− 0000074	− 0000098	− 0000169	− 0000060	− 0000060
6	12	− 0000039	+ 0000001	+ 0000021	− 0000011	− 0000044	− 0000013	+ 0000044	+ 0000017	− 0000013	− 0000019	+ 0000031	− 0000047	− 0000126	+ 0000005	− 0000154
7	12	− 0000009	− 0000046	+ 0000055	− 0000035	− 0000091	+ 0000005	+ 0000015	+ 0000014	− 0000007	+ 0000042	− 0000058	− 0000007	− 0000068	+ 0000017	− 0000118
8	13	+ 0000038	− 0000062	− 0000017	− 0000081	− 0000090	− 0000043	+ 0000027	+ 0000028	+ 0000007	+ 0000011	− 0000068	+ 0000056	− 0000075	− 0000013	− 0000059
9	12	+ 0000043	− 0000026	− 0000043	− 0000029	− 0000022	+ 0000018	+ 0000030	− 0000021	+ 0000055	+ 0000055	+ 0000012	− 0000027	− 0000070	− 0000001	+ 0000011
10	12	+ 0000071	− 0000000	+ 0000036	− 0000067	− 0000090	− 0000028	+ 0000022	− 0000037	− 0000006	+ 0000001	− 0000082	− 0000011	− 0000070	− 0000011	− 0000087
11	12	+ 0000045	− 0000016	+ 0000001	− 0000083	+ 0000017	− 0000066	+ 0000045	− 0000085	− 0000030	+ 0000038	− 0000017	+ 0000067	− 0000030	− 0000028	+ 0000001

These variations are curved in thin lines in fig. 48, being numbered 1 to 20 and −9 to −1 in order.

Colaba Observatory, Bombay.

Curves representing, for a full lunation and for the quarter November to January, that part of the solar diurnal variation of declination which runs through a cycle of change in a lunation.

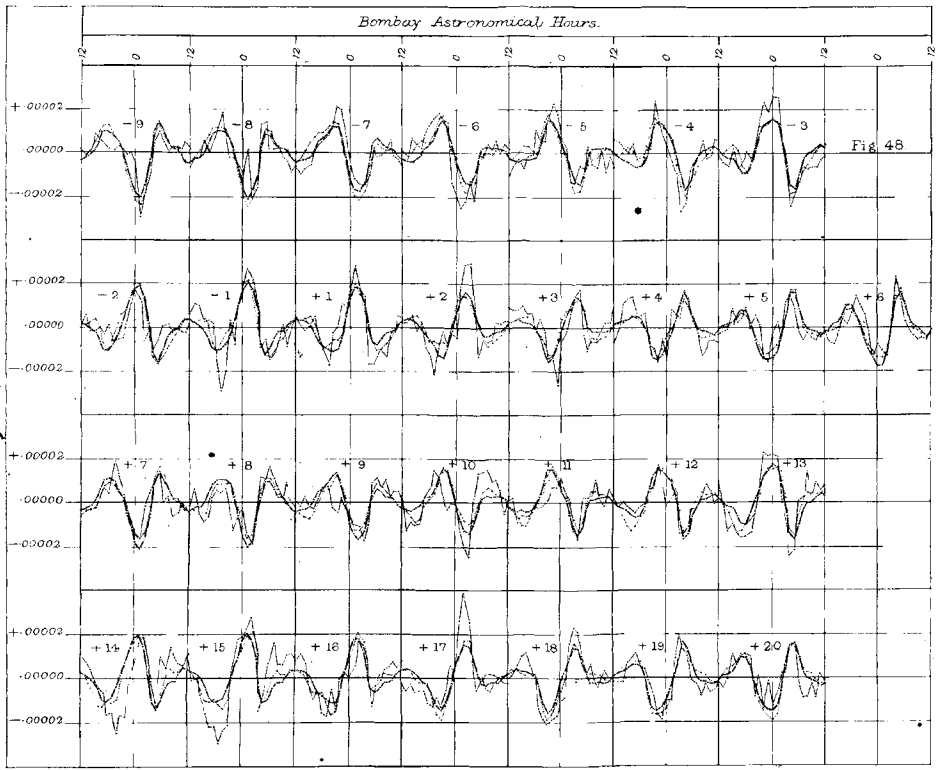


Fig. 48

Dotted curves . . . . . calculated by the formula

$$f_{c_1}(h)\cos\frac{2\pi}{P}t + f_{s_1}(h)\sin\frac{2\pi}{P}t + f_{c_2}(h)\cos 2\frac{2\pi}{P}t + f_{s_2}(h)\sin 2\frac{2\pi}{P}t$$

h being the solar hour, t the age of the moon, and P the mean period of a lunation; and $f_{c_1}(h)$, $f_{s_1}(h)$, *&c. each being a constant solar diurnal variation.*

Thick line curves ——————— calculated by the last two terms only of the same formula

Thin line curves ——— variations given by observation.

An increase (upward movement) of one inch in the ordinates indicates an increas of the easterly magnetic force of ·000048 C. G. S. unit.

The numbers with which the curves are marked represent the days before (−) or after (+) New Moon.

West, Newman, & Co. lith.

19. In calculating luni-solar variations for each day of the moon's age by our extended formula, we carried the harmonic equivalents of the typical variations of lines 1 and 5 of Tables 9 and 10, and of lines *g* and *h* of Tables 11 and 15, to six pairs of terms, and used these equivalents instead of the typical variations from which they were derived. The coefficients found were, for November to January—

TABLE 24.—Declination.

	a_1	b_1	a_2	b_2	a_3	b_3	a_4	b_4	a_5	b_5	a_6	b_6
$f_{r_1}(h)$	+ ·0000005	− ·0000034	+ ·0000006	+ ·0000004	− ·0000002	− ·0000009	− ·0000002	− ·0000005	+ ·0000012	+ ·0000016	+ ·0000011	+ ·0000006
$f_{s_1}(h)$	+ ·0000023	+ ·0000023	+ ·0000010	− ·0000003	− ·0000004	+ ·0000001	+ ·0000008	·0000000	− ·0000004	− ·0000005	− ·0000002	+ ·0000001
$f_{r_2}(h)$	+ ·0000031	+ ·0000026	+ ·0000097	+ ·0000040	+ ·0000033	− ·0000031	+ ·0000001	+ ·0000024	− ·0000007	+ ·0000003	·0000000	− ·0000008
$f_{s_2}(h)$	− ·0000030	+ ·0000031	− ·0000055	+ ·0000077	− ·0000023	+ ·0000023	+ ·0000001	− ·0000009	+ ·0000008	− ·0000015	+ ·0000005	+ ·0000001

TABLE 25.—Horizontal Force.

	a_1	b_1	a_2	b_2	a_3	b_3	a_4	b_4	a_5	b_5	a_6	b_6
$f_{r_1}(h)$	− ·0000020	+ ·0000015	− ·0000021	− ·0000013	+ ·0000005	+ ·0000007	·0000000	+ ·0000013	+ ·0000003	− ·0000002	− ·0000019	− ·0000001
$f_{s_1}(h)$	− ·0000050	− ·0000023	− ·0000023	− ·0000012	+ ·0000004	+ ·0000002	+ ·0000006	− ·0000011	− ·0000008	− ·0000005	− ·0000001	− ·0000008
$f_{r_2}(h)$	+ ·0000006	− ·0000093	+ ·0000001	− ·0000126	− ·0000009	− ·0000053	− ·0000009	− ·0000019	− ·0000006	+ ·0000003	− ·0000004	+ ·0000015
$f_{s_2}(h)$	+ ·0000136	− ·0000017	+ ·0000134	+ ·0000007	+ ·0000033	− ·0000028	+ ·0000005	− ·0000009	− ·0000009	− ·0000011	+ ·0000009	− ·0000010

20. And now, using 12 as the hour of occurrence of new moon on the initial solar day, the luni-solar variations found were as follows :—

TABLE 26.—Declination. November to January. Values, for each Solar Hour of the Moon's Age, of

$$f_{c.1}(h)\cos\left(2\pi\frac{t}{\mathrm{P}}\right)+f_{s.1}(h)\sin\left(2\pi\frac{t}{\mathrm{P}}\right)+f_{c.2}(h)\cos 2\left(2\pi\frac{t}{\mathrm{P}}\right)+f_{s.2}(h)\sin 2\left(2\pi\frac{t}{\mathrm{P}}\right).$$

Bombay astronomical hours.	Days after new moon.														
	−9	−8	−7	−6	−5	−4	−3	−2	−1	+1	+2	+3	+4	+5	+6
12	−·0000036	−·0000042	−·0000040	−·0000033	−·0000020	−·0000002	+·0000015	+·0000030	+·0000039	+·0000041	+·0000035	+·0000024	+·0000009	−·0000012	−·0000024
13	−·0000011	−·0000022	−·0000029	−·0000030	−·0000026	−·0000015	·0000000	+·0000014	+·0000026	+·0000034	+·0000037	+·0000031	+·0000020	+·0000006	−·0000012
14	+·0000023	+·0000012	+·0000003	−·0000002	−·0000002	+·0000003	+·0000012	+·0000024	+·0000034	+·0000041	+·0000044	+·0000039	+·0000027	+·0000010	−·0000013
15	+·0000056	+·0000053	+·0000047	+·0000040	+·0000035	+·0000029	+·0000038	+·0000040	+·0000044	+·0000050	+·0000051	+·0000048	+·0000038	+·0000021	−·0000002
16	+·0000093	+·0000089	+·0000077	+·0000056	+·0000036	+·0000018	+·0000007	+·0000008	+·0000008	+·0000019	+·0000033	+·0000051	+·0000054	+·0000052	+·0000041
17	+·0000125	+·0000115	+·0000088	+·0000048	+·0000007	−·0000033	−·0000062	−·0000075	−·0000073	−·0000054	−·0000023	+·0000012	+·0000044	+·0000070	+·0000080
18	+·0000129	+·0000120	+·0000092	+·0000043	−·0000002	−·0000051	−·0000088	−·0000111	−·0000114	−·0000099	−·0000066	−·0000023	+·0000020	+·0000049	+·0000085
19	+·0000103	+·0000120	+·0000118	+·0000096	+·0000064	+·0000021	−·0000021	−·0000057	−·0000077	−·0000082	−·0000070	−·0000043	−·0000009	+·0000027	+·0000059
20	+·0000055	+·0000109	+·0000146	+·0000161	+·0000152	+·0000122	+·0000076	+·0000026	−·0000023	−·0000059	−·0000078	−·0000078	−·0000046	−·0000017	+·0000018
21	−·0000006	+·0000070	+·0000132	+·0000172	+·0000183	+·0000167	+·0000125	+·0000063	−·0000003	−·0000061	−·0000076	−·0000124	−·0000117	−·0000084	−·0000035
22	−·0000079	−·0000013	+·0000053	+·0000197	+·0000139	+·0000146	+·0000125	+·0000082	+·0000024	−·0000038	−·0000091	−·0000128	−·0000138	−·0000123	−·0000082
23	−·0000155	−·0000108	−·0000018	+·0000020	+·0000081	+·0000122	+·0000142	+·0000135	+·0000103	+·0000055	+·0000004	−·0000058	−·0000099	−·0000118	−·0000114
0	−·0000217	−·0000192	−·0000139	−·0000057	+·0000029	+·0000107	+·0000167	+·0000199	+·0000199	+·0000165	+·0000107	+·0000035	−·0000039	−·0000099	−·0000135
1	−·0000237	−·0000245	−·0000195	−·0000123	−·0000035	+·0000057	+·0000139	+·0000195	+·0000217	+·0000202	+·0000153	+·0000079	−·0000005	−·0000082	−·0000141
2	−·0000179	−·0000211	−·0000216	−·0000184	−·0000125	−·0000051	+·0000028	+·0000095	+·0000139	+·0000154	+·0000139	+·0000094	+·0000032	−·0000035	−·0000095
3	−·0000056	−·0000120	−·0000168	−·0000189	−·0000184	−·0000153	−·0000102	−·0000039	+·0000024	+·0000075	+·0000111	+·0000120	+·0000105	+·0000071	+·0000025
4	+·0000074	+·0000009	−·0000063	−·0000127	−·0000172	−·0000189	−·0000177	−·0000137	−·0000085	−·0000002	+·0000069	+·0000128	+·0000164	+·0000149	+·0000147
5	+·0000128	+·0000087	+·0000026	−·0000043	−·0000106	−·0000152	−·0000173	−·0000165	−·0000128	−·0000069	+·0000002	+·0000075	+·0000135	+·0000173	+·0000181
6	+·0000096	+·0000078	+·0000044	−·0000002	−·0000050	−·0000095	−·0000125	−·0000137	−·0000132	−·0000104	−·0000052	−·0000011	+·0000039	+·0000082	+·0000109
7	+·0000044	+·0000037	+·0000021	−·0000001	−·0000027	−·0000055	−·0000080	−·0000097	−·0000105	−·0000101	−·0000087	−·0000063	−·0000035	−·0000002	+·0000025
8	+·0000021	+·0000017	+·0000009	−·0000003	−·0000016	−·0000033	−·0000049	−·0000058	−·0000072	−·0000075	−·0000073	−·0000053	−·0000048	−·0000027	−·0000006
9	+·0000019	+·0000020	+·0000018	+·0000011	+·0000002	−·0000012	−·0000025	−·0000037	−·0000048	−·0000052	−·0000056	−·0000052	−·0000043	−·0000029	−·0000014
10	−·0000002	+·0000006	+·0000013	+·0000018	+·0000020	+·0000018	+·0000012	+·0000001	−·0000012	−·0000024	−·0000036	−·0000043	−·0000043	−·0000039	−·0000031
11	−·0000034	−·0000025	−·0000012	+·0000005	+·0000019	+·0000031	+·0000037	+·0000035	+·0000026	+·0000012	−·0000003	−·0000022	−·0000036	−·0000044	−·0000047

TABLE 26—continued.

Bombay astronomical hours.	Days after new moon.													
	+7	+8	+9	+10	+11	+12	+13	+14	+15	+16	+17	+18	+19	+20
12	−·0000035	−·0000040	−·0000038	−·0000028	−·0000012	+·0000004	+·0000021	+·0000033	+·0000040	+·0000041	+·0000034	+·0000021	+·0000003	−·0000015
13	−·0000027	−·0000039	−·0000044	−·0000043	−·0000034	−·0000022	−·0000005	+·0000012	+·0000026	+·0000036	+·0000039	+·0000035	+·0000026	+·0000013
14	−·0000035	−·0000054	−·0000068	−·0000074	−·0000074	−·0000063	−·0000046	−·0000025	−·0000003	+·0000017	+·0000032	+·0000041	+·0000043	+·0000038
15	−·0000026	−·0000054	−·0000077	−·0000096	−·0000106	−·0000107	−·0000097	−·0000080	−·0000057	−·0000029	−·0000002	+·0000023	+·0000041	+·0000052
16	+·0000020	−·0000011	−·0000045	−·0000079	−·0000109	−·0000127	−·0000134	−·0000125	−·0000103	−·0000089	−·0000029	+·0000012	+·0000043	+·0000073
17	+·0000074	+·0000051	+·0000013	−·0000015	−·0000071	−·0000107	−·0000125	−·0000127	−·0000109	−·0000074	−·0000027	+·0000022	+·0000069	+·0000104
18	+·0000092	+·0000080	+·0000052	+·0000013	−·0000031	−·0000070	−·0000096	−·0000107	−·0000097	−·0000068	−·0000027	+·0000021	+·0000068	+·0000106
19	+·0000078	+·0000081	+·0000068	+·0000039	·0000000	−·0000043	−·0000082	−·0000109	−·0000120	−·0000112	−·0000088	−·0000047	+·0000001	+·0000048
20	+·0000055	+·0000084	+·0000093	+·0000083	+·0000053	+·0000006	−·0000047	−·0000101	−·0000144	−·0000169	−·0000170	−·0000147	−·0000102	−·0000043
21	+·0000025	+·0000080	+·0000120	+·0000138	+·0000128	+·0000092	+·0000036	−·0000033	−·0000101	−·0000157	−·0000190	−·0000194	−·0000168	−·0000116
22	−·0000024	+·0000042	+·0000101	+·0000145	+·0000166	+·0000157	+·0000123	+·0000065	−·0000003	−·0000072	−·0000129	−·0000165	−·0000173	−·0000154
23	−·0000086	−·0000036	+·0000021	+·0000080	+·0000128	+·0000155	+·0000155	+·0000129	+·0000080	+·0000016	−·0000053	−·0000114	−·0000159	−·0000177
0	−·0000152	−·0000120	−·0000072	−·0000007	+·0000059	+·0000117	+·0000153	+·0000160	+·0000137	+·0000083	+·0000011	−·0000066	−·0000140	−·0000194
1	−·0000170	−·0000164	−·0000123	−·0000058	+·0000021	+·0000099	+·0000161	+·0000193	+·0000191	+·0000154	+·0000096	+·0000001	−·0000091	−·0000169
2	−·0000136	−·0000149	−·0000130	−·0000084	−·0000015	+·0000062	+·0000135	+·0000187	+·0000213	+·0000207	+·0000167	+·0000098	+·0000014	−·0000073
3	−·0000024	−·0000068	−·0000093	−·0000097	−·0000076	−·0000036	+·0000020	+·0000076	+·0000127	+·0000160	+·0000172	+·0000155	+·0000114	+·0000052
4	+·0000102	+·0000040	−·0000027	−·0000083	−·0000123	−·0000136	−·0000122	−·0000082	−·0000026	+·0000040	+·0000097	+·0000138	+·0000155	+·0000143
5	+·0000160	+·0000113	+·0000049	−·0000021	−·0000087	−·0000133	−·0000154	−·0000147	−·0000112	−·0000057	+·0000008	+·0000071	+·0000118	+·0000144
6	+·0000119	+·0000109	+·0000082	+·0000045	+·0000001	−·0000038	−·0000065	−·0000076	−·0000070	−·0000049	−·0000013	+·0000026	+·0000062	+·0000088
7	+·0000049	+·0000054	+·0000069	+·0000067	+·0000055	+·0000041	+·0000026	+·0000014	+·0000007	+·0000007	+·0000011	+·0000020	+·0000031	+·0000040
8	+·0000014	+·0000032	+·0000045	+·0000052	+·0000054	+·0000051	+·0000046	+·0000039	+·0000031	+·0000024	+·0000021	+·0000020	+·0000020	+·0000020
9	+·0000002	+·0000018	+·0000028	+·0000035	+·0000037	+·0000036	+·0000031	+·0000024	+·0000018	+·0000013	+·0000011	+·0000010	+·0000012	+·0000014
10	−·0000018	−·0000003	+·0000011	+·0000025	+·0000031	+·0000036	+·0000035	+·0000029	+·0000019	+·0000009	−·0000001	−·0000008	−·0000012	−·0000010
11	−·0000040	−·0000027	−·0000010	+·0000008	+·0000024	+·0000039	+·0000046	+·0000044	+·0000036	+·0000022	+·0000004	−·0000011	−·0000026	−·0000034

TABLE 27.—Horizontal Force. November to January. Values, for each Solar Hour of the Moon's Age, of

$$f_{c,1}(h)\cos\left(2\pi\frac{t}{\mathrm{P}}\right)+f_{s,1}(h)\sin\left(2\pi\frac{t}{\mathrm{P}}\right)+f_{c,2}(h)\cos 2\left(2\pi\frac{t}{\mathrm{P}}\right)+f_{s,2}(h)\sin 2\left(2\pi\frac{t}{\mathrm{P}}\right).$$

Bombay astronomical hours.	Days after new moon.														
	−9	−8	−7	−6	−5	−4	−3	−2	−1	+1	+2	+3	+4	+5	+6
12	−·0000034	−·0000033	−·0000032	−·0000030	−·0000029	−·0000028	−·0000029	−·0000029	−·0000032	−·0000031	−·0000028	−·0000025	−·0000017	−·0000008	+·0000005
13	−·0000019	−·0000012	−·0000007	−·0000001	+·0000002	+·0000002	·0000000	−·0000005	−·0000009	−·0000014	−·0000018	−·0000018	−·0000015	−·0000010	·0000000
14	−·0000013	+·0000005	+·0000022	+·0000034	+·0000037	+·0000035	+·0000025	+·0000011	−·0000002	−·0000014	−·0000021	−·0000022	−·0000016	−·0000005	+·0000010
15	−·0000018	·0000000	+·0000014	+·0000022	+·0000021	+·0000012	−·0000003	−·0000022	−·0000039	−·0000051	−·0000055	−·0000050	−·0000035	−·0000012	+·0000021
16	−·0000067	−·0000048	−·0000027	−·0000008	+·0000003	+·0000005	−·0000001	−·0000017	−·0000036	−·0000053	−·0000065	−·0000069	−·0000059	−·0000032	−·0000008
17	−·0000138	−·0000100	−·0000051	−·0000003	+·0000037	+·0000063	+·0000071	+·0000060	+·0000037	+·0000004	−·0000030	−·0000061	−·0000068	−·0000062	−·0000039
18	−·0000170	−·0000116	−·0000048	+·0000021	+·0000077	+·0000118	+·0000134	+·0000126	+·0000098	+·0000054	+·0000006	−·0000037	−·0000066	−·0000073	−·0000059
19	−·0000163	−·0000125	−·0000049	−·0000001	+·0000061	+·0000113	+·0000143	+·0000150	+·0000130	+·0000090	+·0000036	−·0000020	−·0000068	−·0000099	−·0000109
20	−·0000167	−·0000179	−·0000156	−·0000105	−·0000038	+·0000041	+·0000110	+·0000157	+·0000175	+·0000161	+·0000136	+·0000046	−·0000033	−·0000109	−·0000169
21	−·0000165	−·0000236	−·0000260	−·0000238	−·0000171	−·0000072	+·0000040	+·0000144	+·0000218	+·0000255	+·0000236	+·0000175	+·0000077	−·0000035	−·0000149
22	−·0000076	−·0000201	−·0000295	−·0000321	−·0000295	−·0000219	−·0000102	+·0000032	+·0000158	+·0000250	+·0000293	+·0000287	+·0000221	+·0000113	−·0000020
23	+·0000091	−·0000062	−·0000201	−·0000300	−·0000344	−·0000327	−·0000253	−·0000135	+·0000001	+·0000131	+·0000233	+·0000287	+·0000281	+·0000221	+·0000112
0	+·0000243	+·0000110	−·0000034	−·0000164	−·0000259	−·0000303	−·0000292	−·0000229	−·0000130	−·0000016	+·0000092	+·0000182	+·0000223	+·0000213	+·0000154
1	+·0000312	+·0000233	+·0000125	−·0000005	−·0000104	−·0000185	−·0000226	−·0000223	−·0000180	−·0000106	−·0000017	+·0000070	+·0000134	+·0000161	+·0000149
2	+·0000323	+·0000287	+·0000211	+·0000108	−·0000005	−·0000107	−·0000184	−·0000222	−·0000217	−·0000173	−·0000099	−·0000009	+·0000076	+·0000139	+·0000171
3	+·0000285	+·0000276	+·0000224	+·0000140	+·0000087	−·0000067	−·0000152	−·0000220	−·0000241	−·0000221	−·0000164	−·0000082	+·0000009	+·0000093	+·0000152
4	+·0000192	+·0000210	+·0000197	+·0000152	+·0000085	+·0000003	−·0000076	−·0000146	−·0000177	−·0000204	−·0000178	−·0000142	−·0000076	−·0000006	+·0000058
5	+·0000067	+·0000120	+·0000156	+·0000170	+·0000151	+·0000146	+·0000061	−·0000005	−·0000068	−·0000119	−·0000148	−·0000152	−·0000132	−·0000088	−·0000034
6	−·0000017	+·0000051	+·0000113	+·0000155	+·0000172	+·0000164	+·0000129	+·0000077	+·0000017	−·0000040	−·0000082	−·0000106	−·0000105	−·0000081	−·0000040
7	−·0000050	+·0000010	+·0000064	+·0000104	+·0000126	+·0000127	+·0000108	+·0000074	+·0000032	−·0000012	−·0000042	−·0000059	−·0000058	−·0000040	−·0000008
8	−·0000065	−·0000012	−·0000040	+·0000033	+·0000110	+·0000120	+·0000111	+·0000085	+·0000048	·0000000	−·0000026	−·0000049	−·0000059	−·0000050	−·0000028
9	−·0000093	−·0000033	+·0000029	+·0000087	+·0000129	+·0000152	+·0000150	+·0000127	+·0000086	+·0000036	−·0000012	−·0000052	−·0000076	−·0000080	−·0000064
10	−·0000094	−·0000040	+·0000017	+·0000068	+·0000105	+·0000125	+·0000125	+·0000105	+·0000070	+·0000027	−·0000010	−·0000042	−·0000058	−·0000068	−·0000040
11	−·0000065	−·0000040	−·0000015	+·0000007	+·0000022	+·0000030	+·0000027	+·0000019	+·0000005	−·0000010	−·0000023	−·0000028	−·0000025	−·0000015	+·0000005

TABLE 27—continued.

Bombay astronomical hours.	Days after new moon.													
	+7	+8	+9	+10	+11	+12	+13	+14	+15	+16	+17	+18	+19	+20
12	+·0000020	+·0000034	+·0000045	−·0000012	+·0000062	+·0000062	+·0000058	+·0000049	+·0000036	+·0000021	+·0000007	−·0000007	−·0000019	−·0000027
13	+·0000009	+·0000020	+·0000029	+·0000034	+·0000036	+·0000034	+·0000029	+·0000020	+·0000007	−·0000003	−·0000012	−·0000020	−·0000024	−·0000024
14	+·0000026	+·0000040	+·0000049	+·0000050	+·0000043	+·0000030	+·0000015	−·0000012	−·0000033	−·0000050	−·0000060	−·0000063	−·0000057	−·0000043
15	+·0000045	+·0000060	+·0000065	+·0000060	+·0000085	+·0000067	+·0000042	+·0000013	−·0000016	−·0000041	−·0000055	−·0000063	−·0000060	−·0000046
16	+·0000029	+·0000066	+·0000099	+·0000123	+·0000133	+·0000128	+·0000108	+·0000076	+·0000039	−·0000003	−·0000037	−·0000066	−·0000082	−·0000085
17	·0000000	+·0000046	+·0000093	+·0000133	+·0000157	+·0000161	+·0000143	+·0000104	+·0000049	−·0000043	−·0000072	−·0000121	−·0000155	−·0000164
18	−·0000025	+·0000023	+·0000073	+·0000148	+·0000148	+·0000156	+·0000137	+·0000095	+·0000033	−·0000089	−·0000107	−·0000164	−·0000200	−·0000189
19	−·0000023	−·0000058	−·0000009	+·0000045	+·0000104	+·0000126	+·0000136	+·0000122	+·0000083	+·0000023	−·0000038	−·0000098	−·0000145	−·0000128
20	−·0000201	−·0000197	−·0000161	−·0000096	−·0000015	+·0000069	+·0000140	+·0000139	+·0000206	+·0000137	+·0000139	+·0000067	−·0000014	−·0000091
21	−·0000240	−·0000292	−·0000294	−·0000247	−·0000156	−·0000037	+·0000085	+·0000197	+·0000275	+·0000308	+·0000289	+·0000222	+·0000120	+·0000001
22	−·0000184	−·0000255	−·0000324	−·0000353	−·0000283	−·0000181	−·0000049	+·0000097	+·0000228	+·0000321	+·0000358	+·0000337	+·0000259	+·0000138
23	−·0000122	−·0000157	−·0000266	−·0000333	−·0000341	−·0000286	−·0000180	−·0000040	+·0000145	+·0000254	+·0000353	+·0000396	+·0000375	+·0000294
0	+·0000054	−·0000056	−·0000181	−·0000274	−·0000324	−·0000318	−·0000255	−·0000143	−·0000068	+·0000139	+·0000282	+·0000362	+·0000400	+·0000331
1	+·0000097	+·0000014	−·0000085	−·0000180	−·0000253	−·0000291	−·0000281	−·0000227	−·0000130	−·0000010	+·0000118	+·0000227	+·0000313	+·0000351
2	+·0000158	+·0000112	+·0000033	−·0000062	−·0000156	−·0000232	−·0000272	−·0000268	−·0000220	−·0000133	−·0000021	+·0000097	+·0000207	+·0000285
3	+·0000127	+·0000162	+·0000113	+·0000039	−·0000051	−·0000134	−·0000197	−·0000215	−·0000212	−·0000160	−·0000077	+·0000033	+·0000128	+·0000215
4	+·0000106	+·0000130	+·0000125	+·0000093	+·0000041	−·0000012	−·0000078	−·0000120	−·0000138	−·0000128	−·0000089	−·0000032	+·0000041	+·0000112
5	+·0000042	+·0000056	+·0000105	+·0000116	+·0000102	+·0000067	+·0000017	−·0000037	−·0000086	−·0000120	−·0000132	−·0000173	−·0000100	−·0000029
6	+·0000010	+·0000060	+·0000099	+·0000117	+·0000139	+·0000083	+·0000034	−·0000063	−·0000088	−·0000140	−·0000174	−·0000182	−·0000162	−·0000118
7	+·0000030	+·0000070	+·0000098	+·0000108	+·0000102	+·0000076	+·0000031	−·0000023	−·0000087	−·0000127	−·0000161	−·0000172	−·0000160	−·0000129
8	+·0000005	+·0000010	+·0000071	+·0000091	+·0000094	+·0000080	+·0000048	+·0000004	+·0000004	−·0000070	−·0000092	−·0000149	−·0000149	−·0000129
9	−·0000082	+·0000009	+·0000050	+·0000082	+·0000099	+·0000095	+·0000071	+·0000029	−·0000043	−·0000079	−·0000128	−·0000160	−·0000170	−·0000158
10	−·0000010	+·0000028	+·0000063	+·0000089	+·0000101	+·0000094	+·0000068	+·0000026	−·0000025	−·0000078	−·0000123	−·0000153	−·0000159	−·0000148
11	+·0000028	+·0000053	+·0000074	+·0000088	+·0000091	+·0000082	+·0000062	+·0000033	−·0000001	−·0000034	−·0000063	−·0000083	−·0000089	−·0000089

F 2

21. The numbers of Table 26 are curved in dotted lines in fig. 48. The general correspondence of fact, as indicated by the thin-line curve, with our formula, as indicated by the dotted curves, cannot fail to arrest the attention of the reader; and, whatever be the physical conditions lying behind the phenomena, it cannot but be helpful towards their discovery that a compact mental grasp of the phenomena, such as the formula affords, should take the place of such notions of disconnected variations as are the first outcome of a study of the observations.

22. The numbers of Table 27 are curved in dotted lines in fig. 49, and on the same form are curved, in thin lines, the observed lunar diurnal variations of horizontal force, taken from Column 2 of Tables 5 to 8, for each of the eight phases of the moon. Here again the comparison of observation, as indicated by the thin-line curves, with the formula, through its representative dotted curves, shows remarkably close agreement.

23. That in their more prominent inflexions the dotted curves of fig. 48 are generally of smaller range than the thin-line curves is sufficiently explained by the fact that the typical variations for each phase are averages for three or four consecutive days, whilst the thin-line curves represent variations for first days, second days, third days, &c., after new moon—all single days of the moon's age. Indeed, it is easy to show that the typical variations $f_{c.1}(h)$, $f_{s.1}(h)$ should have been multiplied by $\frac{\frac{4\pi}{29\cdot53}}{\sin\frac{4\pi}{29\cdot53}} = 1\cdot031$ when derived from the observed variations at the quarters, and by $\frac{\frac{3\cdot39\pi}{29\cdot53}}{\sin\frac{3\cdot39\pi}{29\cdot53}} = 1\cdot022$ when derived from the observed variations at the eighths phases; and similarly that $f_{c.2}(h)$, $f_{s.2}(h)$ should have been multiplied by $\frac{\frac{8\pi}{29\cdot53}}{\sin\frac{8\pi}{29\cdot53}} = 1\cdot132$ and by $\frac{\frac{6\cdot78\pi}{29\cdot53}}{\sin\frac{6\cdot78\pi}{29\cdot53}} = 1\cdot092$ in the same two cases respectively. The inadvertent omission to apply these factors is most influential in respect of the larger of them (1·132 and 1·092), since the range of the $f_{c.2}(h)$, $f_{s.2}(h)$ variations is much greater than that of the $f_{c.1}(h)$ and $f_{s.1}(h)$.

24. In the case of the horizontal force curves (fig. 49) the factors would, if applied, affect both the thick-line and the thin-line curves alike, the latter representing the data from which the former were constructed; here, accordingly, the two sets of curves approach more nearly to identity of range.

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Curves representing, for a full lunation and for the quarter November to January, that part of the Solar diurnal variation of the horizontal force which runs through a cycle of change in a lunation.

Fig. 49.

Dotted curves . . . . . *calculated by the formula*

$$f_{c,1}(h)\cos\frac{2\pi}{P}t + f_{s,1}(h)\sin\frac{2\pi}{P}t + f_{c,2}(h)\cos 2\frac{2\pi}{P}t + f_{s,2}(h)\sin 2\frac{2\pi}{P}t$$

h being the solar hour, t the age of the moon, and P the mean period of a lunation; and $f_{c,1}(h)$, $f_{s,1}(h)$, *&c each being a constant solar diurnal variation.*

Thick line curves ———— *calculated by the last two terms only of the same formula.*

Fine line curves . . . *variations given by observation.*

An increase (upward movement) of one inch in the ordinates indicates an increase of the northerly magnetic force of ·000048 C.G.S. unit.

The numbers with which the curves are marked represent the days before (−) or after (+) New Moon.

West, Newman & Co. lith.

25. The thick lines of figs. 48 and 49 have been drawn to represent the two last terms alone of our formula, viz., of

$$f_{c.2}(h)\cos 2\left(\frac{2\pi}{\mathrm{P}}t\right)+f_{s.2}\sin 2\left(\frac{2\pi}{\mathrm{P}}t\right).$$

Noticing that they deviate but little from the dotted lines, it may be inferred that the bulk of the systematic part of the variations is embraced by the restricted formula; and accordingly it is to that part of the variation that goes through a cycle of change in half a lunation that attention should first be directed in seeking for efficient physical causes.

TREVANDRUM.

26. Having thus found that order and system of a simple kind pervade the manifestations of minute lunar variations of magnetic force at Bombay, we turn with interest to records of a similar nature obtained at the near, but more nearly magnetically equatorial, station of Trevandrum. In a volume entitled 'Observations of Magnetic Declination made at Trevandrum and Agustia Malley in the Observatories of H. H. the MAHARAJAH of Travancore,' and published by H. S. KING and Co., of London, in 1874, the late JOHN ALLAN BROUN discussed the declination observations made at Trevandrum during the ten years 1854 to 1864, and—by a method of his own, which is, in essential points, similar to that described in the preceding pages—obtained values of the lunar diurnal variations for each month of the year and at each of the four quarters of the moon. Curves representing these variations appear as Plate 6 of the volume, and a glance at those for the months December and January, which—as at Bombay—have the largest range, is sufficient to show that our formula would correctly represent their principal features at each of the four quarters of the moon; indeed, those curves have a close resemblance to the corresponding winter curves for Bombay. An inspection of the curves for all the months leads to a suspicion that a period of ten years is scarcely sufficient to secure a counterbalancing, in all months, of casual irregularities; but, by combining together the variations of those consecutive months, the curves of which are similar in character, greater regularity is obtained, and the nature of the change of the typical variations with change of season is more distinctly brought out. The grouping of months adopted with these objects in view was as follows, viz.:—(1) December and January; (2) February and March; (3) April to June; (4) July to September; and (5) October and November. The average lunar diurnal variations for these several groups of months were calculated from the variations for individual months given in Tables XXXVII. to XL. (pages 125 and 126) of the book referred to. These average variations, which were expressed in minutes of arc, were then converted into force by multiplying by an adopted value of the horizontal force at Trevandrum (0·37141 C.G.S. unit), and by sine 1′, with results that are exhibited in the following Tables.

TABLE 28.—Declination. Trevandrum.

Twenty-fifths of Trevandrum lunar day.	0	1	2	3	4	5	6	7	8	9	10
New Moon	+·000054	+·000030	+·000009	−·000015	−·000024	−·000026	−·000022	−·000011	−·000006	−·000002	−·000001
First Quarter	+·000014	+·000011	+·000002	+·000005	·000000	−·000004	−·000007	−·000006	−·000007	−·000005	+·000002
Full Moon	+·000003	+·000005	+·000005	·000000	−·000007	−·000017	−·000025	−·000026	−·000021	−·000009	+·000002
Last Quarter	+·000023	+·000026	+·000016	−·000002	−·000020	−·000027	−·000037	−·000032	−·000019	−·000001	+·000019

TABLE 29.—Declination. Trevandrum.

Twenty-fifths of Trevandrum lunar day.	0	1	2	3	4	5	6	7	8	9	10
New Moon	+·000015	+·000012	+·000001	−·000010	−·000019	−·000022	−·000016	−·000014	−·000009	−·000003	−·000002
First Quarter	+·000014	+·000005	−·000001	−·000002	−·000004	−·000005	−·000008	−·000007	−·000006	−·000004	·000000
Full Moon	+·000002	−·000002	−·000005	−·000010	−·000013	−·000015	−·000017	−·000015	−·000008	+·000003	+·000019
Last Quarter	+·000007	+·000003	−·000009	−·000017	−·000023	−·000022	−·000011	−·000001	+·000006	+·000013	+·000018

TABLE 30.—Declination. Trevandrum.

Twenty-fifths of Trevandrum lunar day.	0	1	2	3	4	5	6	7	8	9	10
New Moon	−·000015	−·000018	−·000013	−·000006	·000000	+·000005	+·000005	+·000003	+·000001	+·000002	+·000003
First Quarter	−·000003	−·000003	·000000	·000000	−·000003	−·000006	−·000004	−·000006	−·000004	−·000004	−·000002
Full Moon	+·000008	+·000005	+·000004	·000000	·000000	−·000001	−·000001	+·000003	+·000006	+·000006	+·000002
Last Quarter	−·000001	−·000005	−·000011	−·000009	−·000010	−·000006	+·000001	+·000006	+·000009	+·000010	+·000001

TABLE 31.—Declination. Trevandrum.

Twenty-fifths of Trevandrum lunar day.	0	1	2	3	4	5	6	7	8	9	10
New Moon	−·000022	−·000017	−·000004	+·000003	+·000007	+·000010	+·000006	+·000002	+·000001	−·000004	−·000002
First Quarter	+·000001	+·000004	+·000003	+·000002	+·000004	+·000004	+·000003	+·000001	+·000001	+·000001	−·000003
Full Moon	·000000	+·000004	+·000008	+·000008	+·000011	+·000013	+·000019	+·000018	+·000011	+·000001	−·000007
Last Quarter	−·000006	−·000004	+·000006	+·000013	+·000008	+·000008	+·000009	+·000005	·000000	−·000007	−·000002

December and January.

11	12	13	14	15	16	17	18	19	20	21	22	23	24*
·000000	+·000003	+·000008	+·000006	+·000003	−·000005	−·000015	−·000029	−·000033	−·000020	−·000004	+·000014	+·000037	+·000051
+·000009	+·000022	+·000032	+·000032	+·000013	−·000012	−·000034	−·000040	−·000037	−·000027	−·000006	+·000008	+·000019	+·000015
+·000024	+·000040	+·000033	+·000025	+·000008	−·000006	−·000010	−·000010	−·000009	−·000005	−·000002	−·000002	·000000	+·000004
+·000022	+·000015	+·000009	+·000003	+·000001	·000000	−·000003	−·000008	−·000008	−·000007	−·000004	+·000002	+·000010	+·000024

February and March.

11	12	13	14	15	16	17	18	19	20	21	22	23	24
+·000001	+·000004	+·000008	+·000010	+·000012	+·000008	+·000002	−·000007	−·000007	−·000006	+·000001	+·000012	+·000016	+·000021
+·000008	+·000011	+·000012	+·000006	+·000002	−·000013	−·000023	−·000020	−·000016	−·000005	+·000008	+·000017	+·000015	+·000017
+·000026	+·000019	+·000012	+·000005	+·000001	−·000005	−·000006	−·000002	+·000001	+·000002	−·000001	+·000003	+·000003	+·000004
+·000016	+·000010	+·000005	+·000002	+·000003	+·000004	·000000	−·000003	−·000006	−·000004	−·000002	·000000	+·000004	+·000005

April to June.

11	12	13	14	15	16	17	18	19	20	21	22	23	24
+·000005	+·000004	+·000003	+·000004	+·000003	−·000003	−·000003	−·000004	+·000001	+·000006	+·000010	+·000011	+·000005	−·000007
−·000002	−·000006	−·000007	−·000008	−·000005	−·000002	+·000004	+·000008	+·000012	+·000013	+·000014	+·000008	+·000006	·000000
−·000004	−·000007	−·000006	−·000008	−·000007	−·000006	·000000	+·000001	−·000002	−·000001	−·000001	+·000001	+·000004	+·000005
−·000001	−·000002	−·000001	·000000	−·000003	−·000005	−·000003	−·000003	−·000001	+·000002	+·000006	+·000011	+·000009	+·000004

July to September.

11	12	13	14	15	16	17	18	19	20	21	22	23	24
−·000001	−·000001	+·000001	+·000001	+·000003	+·000006	+·000011	+·000015	+·000013	+·000009	+·000003	−·000007	−·000012	−·000018
−·000009	−·000013	−·000010	−·000007	+·000001	+·000006	+·000009	+·000009	+·000006	+·000004	·000000	−·000008	−·000008	−·000002
−·000010	−·000008	−·000014	−·000012	−·000007	+·000001	+·000003	+·000002	−·000010	−·000013	−·000009	−·000008	−·000002	−·000001
−·000006	−·000004	−·000003	+·000003	+·000003	+·000001	+·000004	−·000001	−·000003	−·000004	−·000003	−·000003	−·000006	−·000010

* In Baoun's mode of reduction the lunar day is divided into 25 parts.

TABLE 32.—Declination. Trevandrum.

Twenty-fifths of Trevandrum lunar day.	0	1	2	3	4	5	6	7	8	9	10
New Moon	+·000019	+·000014	+·000001	−·000007	−·000011	−·000015	−·000013	−·000010	−·000007	−·000004	−·000002
First Quarter	+·000006	·000000	−·000003	−·000005	−·000007	−·000008	−·000008	−·000009	−·000008	−·000012	−·000015
Full Moon	+·000007	+·000007	+·000009	+·000005	+·000002	−·000002	−·000003	−·000012	−·000014	−·000014	−·000008
Last Quarter.	+·000003	+·000001	+·000003	−·000006	−·000008	−·000009	−·000008	−·000008	−·000006	+·000002	+·000007

27. By treating each of these sets of numbers in the manner described in paragraphs 8

TABLE

Twenty-fifths of a solar day after noon.		0	1	2	3	4	5	6	7	8	9	10
December and January	$f_{c,1}(h)$	+·000009	·000000	−·000004	−·000008	−·000008	−·000008	−·000006	−·000002	−·000002	·000000	·000000
	$f_{c,1}(h)$	−·000001	−·000001	+·000002	−·000001	·000000	−·000002	+·000001	+·000003	·000000	+·000002	+·000001
	$f_{c,2}(h)$	+·000041	+·000028	+·000010	−·000008	−·000018	−·000017	−·000014	−·000009	−·000003	−·000002	·000000
February and March	$f_{c,1}(h)$	·000000	+·000002	−·000001	−·000004	−·000007	−·000009	−·000008	−·000008	−·000005	−·000003	−·000003
	$f_{s,1}(h)$	−·000005	−·000004	−·000001	+·000001	−·000001	+·000002	+·000003	+·000001	−·000002	−·000003	−·000003
	$f_{c,2}(h)$	+·000013	+·000006	−·000004	−·000011	−·000014	−·000014	−·000010	−·000005	−·000002	−·000002	+·000001
April to June	$f_{c,1}(h)$	−·000004	−·000006	−·000003	·000000	+·000001	+·000002	+·000003	+·000002	+·000001	+·000001	·000000
	$f_{s,1}(h)$	+·000004	+·000003	+·000002	+·000001	+·000003	+·000001	−·000001	−·000001	+·000001	+·000002	+·000001
	$f_{c,2}(h)$	−·000009	−·000012	−·000011	−·000007	−·000002	+·000002	+·000002	+·000001	·000000	+·000002	+·000003
July to September . .	$f_{c,1}(h)$	−·000006	−·000002	+·000003	+·000003	+·000002	+·000003	+·000005	+·000007	+·000006	+·000002	+·000001
	$f_{s,1}(h)$	·000000	+·000001	+·000002	−·000002	−·000002	+·000002	+·000002	+·000002	·000000	·000000	+·000001
	$f_{c,2}(h)$	−·000012	−·000009	−·000002	+·000003	+·000005	+·000005	+·000001	−·000003	−·000004	−·000004	−·000003
October and November	$f_{c,1}(h)$	+·000008	+·000004	−·000003	−·000004	−·000004	−·000006	−·000006	−·000005	−·000005	−·000004	−·000003
	$f_{s,1}(h)$	·000000	+·000001	+·000002	+·000002	·000000	·000000	−·000002	−·000003	−·000004	−·000004	−·000004
	$f_{c,2}(h)$	+·000010	+·000008	+·000002	−·000005	−·000008	−·000010	−·000007	−·000004	−·000002	·000000	+·000002

These variations are curved in figs. 17 to 21 and 38 to 47.

October and November.

11	12	13	14	15	16	17	18	19	20	21	22	23	24
+·000002	+·000004	+·000004	+·000006	+·000006	+·000003	−·000002	−·000008	−·000008	−·000005	·000000	+·000005	+·000010	+·000016
−·000009	−·000001	+·000013	+·000016	+·000018	+·000010	+·000006	−·000003	−·000009	−·000004	+·000001	+·000008	+·000009	+·000012
−·000004	+·000002	+·000006	+·000007	+·000005	−·000003	−·000003	−·000003	·000000	+·000002	+·000003	+·000005	+·000002	+·000008
+·000012	+·000011	+·000008	+·000006	+·000006	+·000002	+·000001	−·000001	−·000004	−·000004	−·000006	−·000003	·000000	+·000001

and 14, the several values of the typical variations $f(h)$ were obtained as follows:—

33.

11	12	13	14	15	16	17	18	19	20	21	22	23	24
−·000001	·000000	+·000002	·000000	·000000	−·000001	−·000002	−·000004	−·000004	+·000002	+·000006	+·000009	+·000012	+·000009
+·000001	+·000001	·000000	−·000001	−·000002	−·000002	−·000004	−·000001	+·000004	+·000006	+·000003	·000000	−·000005	−·000004
+·000003	+·000005	+·000006	+·000006	+·000003	−·000004	−·000013	−·000024	−·000029	−·000024	−·000010	+·000008	+·000027	+·000029
−·000001	+·000001	+·000004	+·000007	+·000010	+·000010	+·000008	+·000004	+·000004	+·000003	+·000002	·000000	−·000003	·000000
−·000002	−·000002	−·000001	−·000002	−·000002	−·000001	+·000002	+·000002	+·000003	+·000004	+·000007	+·000004	·000000	−·000002
+·000003	+·000005	+·000005	+·000004	+·000002	−·000001	−·000006	−·000010	−·000010	−·000005	+·000002	+·000014	+·000021	+·000020
·000000	−·000001	−·000002	·000000	·000000	−·000001	−·000001	−·000001	·000000	+·000001	+·000002	+·000004	+·000002	−·000001
−·000002	−·000001	−·000003	−·000004	−·000006	−·000006	−·000005	−·000004	−·000002	·000000	+·000002	+·000004	+·000006	+·000005
+·000005	+·000004	+·000004	+·000002	·000000	−·000003	−·000002	·000000	+·000003	+·000006	+·000008	+·000007	+·000001	−·000005
·000000	·000000	−·000001	−·000003	−·000002	−·000002	·000000	−·000001	−·000003	−·000003	−·000001	−·000002	−·000002	−·000005
+·000001	+·000002	+·000002	+·000002	+·000002	+·000001	·000000	−·000003	−·000003	−·000004	−·000004	−·000002	·000000	·000000
−·000002	−·000001	+·000001	+·000002	+·000003	+·000006	+·000010	+·000013	+·000012	+·000008	·000000	−·000007	−·000009	−·000011
−·000002	−·000002	−·000002	−·000001	·000000	·000000	−·000001	−·000001	+·000001	+·000004	+·000007	+·000008	+·000008	+·000008
−·000004	−·000003	−·000002	−·000002	−·000004	−·000007	−·000005	−·000001	+·000006	+·000007	+·000010	+·000008	+·000007	+·000003
+·000004	+·000006	+·000006	+·000007	+·000007	+·000006	+·000002	−·000004	−·000008	−·000009	−·000007	−·000002	+·000002	+·000006

28. On these curves we first remark that, as at Bombay, the variations of the $f_{c.1}(h)$ and $f_{s.1}(h)$ types are quite subordinate in magnitude to those of the $f_{c.2}(h)$ type; that the $f_{c.2}(h)$ curve is twice reversed in the course of the year, and that, whilst for December and January (fig. 17) it has a greater range than the corresponding winter curve (fig. 1) for Bombay, the reverse curve for July to September (fig. 20) has a smaller range than the corresponding autumn curve (fig. 4) for Bombay. The relation of the $f_{c.2}(h)$ curves of the two stations generally is such that the superposition of a constant variation of the character of the winter $f_{c.2}(h)$ curve, but of smaller range, upon the Bombay curves for each season would convert these into curves having the same principal characteristics as those of the same season for Trevandrum; and, in agreement with this, the reversal in the first half of the year occurs later at Trevandrum than at Bombay, and the reversal in the last half-year occurs earlier than at Bombay.

And here again we must insist on the reality of the variations now brought to light as true physical phenomena, which exhibit themselves not alone at a single point on the earth's surface, but are well marked in the observations of two stations that differ by nearly ten degrees in latitude, and the observatories at which were necessarily furnished with independent instruments, and had independent directors.

Postscript.

(Added September 23, 1886.)

The late John Allan Broun, in discussing the Trevandrum observations for the ten years 1854 to 1864, came to the conclusion that in the lunar diurnal variations of declination in each month of the year the amount of movement is, as in the solar diurnal variation, greater during the day than during the night; and the writer of this paper has shown in it that in each of four seasons of the year the same holds at Bombay with respect both to the declination and horizontal force. Whilst admitting, however, that Broun has priority of publication of this fact as regards the declination at Trevandrum, the writer avers that he has in no way been guided by Broun's previous investigation, nor was he aware of the existence of Broun's paper * when he made the discovery with respect to the declination at Bombay. Moreover, the writer's line of investigation was that of Sabine, modified by himself, and not that of Broun; and an account of the first results of its employment was read before the Royal Society on the 1st February, 1872, a date antecedent to the reading of Broun's paper before the Royal Society of Edinburgh, which did not take place till the 6th May, 1872. The writer also readily acknowledges that in the paper already referred to Broun enunciated some relations of the movements near sunrise in the lunar diurnal variations of declination in different months, which relations fit in well with the idea of a luni-solar variation when once that idea is conceived; but he finds

* 'Transactions of the Royal Society of Edinburgh,' vol. 26, page 735.

no trace of that idea in any of BROUN'S writings. Neither does he find in BROUN'S writings any of the following results that are described in the present paper, viz. :—

(1.) The discovery of relations subsisting between the lunar diurnal variation of declination *as a whole* at one phase of a lunation with the same at other phases in each season of the year [this as distinguished from the movements that occur *near sunrise*, and the nature of which was described by BROUN].

(2.) The discovery that a part, being the bulk of the whole, of the lunar diurnal variation runs through a cycle of change in a lunation; to this part the name of the luni-solar variation is given.

(3.) A hypothesis is advanced—a hypothesis of phenomenal relations and not of physical causation—that the luni-solar variation of a given season is a combination of solar diurnal variations of constant types that go through cycles of wave-like change of amplitude in the periods of a lunation, half a lunation, &c., &c., and a formula is found to give expression to this hypothesis.

(4.) Following up this hypothesis, the observations of declination for the quarter November to January of the years 1846 to 1870 are divided into categories of solar days according to the age of the moon; and the excess solar diurnal variation—the excess over the mean solar diurnal variation for the approximate full lunation—is entered in the Tables for each day, and the mean value is calculated for each category. Curves representing these mean excess solar diurnal variations for each day of the moon's age are found to agree fairly well with the formula expressing the luni-solar variation of the quarter November to January, a result which tends to confirm the hypothesis.

(5.) The mode of change, from season to season, of the character of the elements of the luni-solar variations is described.

(6.) All the results, without exception, of the investigation with reference to the lunar variations of horizontal force must be placed on this list.

(7.) That the luni-solar variations of declination are related to those of the horizontal force in the following manner, viz. :—(*a*) In the winter season the luni-solar variation of declination due to any phase of the moon is similar to the luni-solar variation of horizontal force due to a phase later by one-eighth of a lunation; and (*b*) in the summer and autumn seasons it is, on the other hand, the luni-solar variations of horizontal force that precede by an eighth of a lunation the similar variations of declination.

(8.) It is shown that, when the Bombay observations have pointed the way, BROUN'S determinations of the lunar diurnal variations of declination at Trevandrum for the four quarters of the moon in each month of the year, when properly treated, support the hypothesis of result (3).

APPENDIX II.

Luni-solar Variation of Magnetic Declination at Batavia, and references to later extensions of the investigations of the preceding paper.

30. In the Batavia Magnetical and Meteorological Observations, Vol. III., pages 187* to 190,* Bergsma investigates the lunar diurnal variations of magnetic declination at that place, and on page 188* (Table 268) he gives the variations separately for each quarter of the moon as deduced from the observations of the seven years 1867·50 to 1871·50 and 1872·50 to 1875·50 irrespective of the season of the year at which a particular phase of the moon may have occurred. All the lunar days on which New Moon occurred and the days immediately preceding and following them were classed as belonging to New Moon, and similarly three days in each lunation were classed as belonging to First Quarter, Full Moon and Last Quarter. Expressed in seconds of arc the variations are as follows :—

Batavia Lunar Hours.	New Moon.	First Quarter.	Full Moon.	Last Quarter.
	"	"	"	"
0 ...	16·8 E.	6·9 E.	5·2 E.	6·0 E.
1 ...	10·8 E.	4·7 E.	4·7 E.	9·9 E.
2 ...	5·6 E.	4·3 E.	3·9 E.	8·2 E.
3 ...	2·2 E.	0·9 E.	3·4 E.	3·9 E.
4 ...	1·3 W.	0·4 E.	0·4 W.	6·5 W.
5 ...	3·4 W.	3·4 W.	4·7 W.	19·0 W.
6 ...	2·6 W.	3·4 W.	8·6 W.	22·4 W.
7 ...	1·3 W.	4·7 W.	13·4 W.	18·5 W.
8 ...	1·7 W.	3·0 W.	11·6 W.	9·5 W.
9 ...	2·2 W.	4·7 W.	5·2 W.	1·3 W.
10 ...	2·6 W.	4·3 W.	6·5 E.	3·4 E.
11 ...	2·6 W.	3·9 W.	12·5 E.	3·0 E.
12 ...	2·6 W.	1·7 E.	14·2 E.	0·9 E.
13 ...	2·2 W.	9·1 E.	7·8 E.	0·4 E.
14 ...	0·4 W.	9·9 E.	0·9 E.	0·9 E.
15 ...	1·7 E.	6·0 E.	4·7 W.	0·4 E.
16 ...	0·4 W.	2·6 W.	7·3 W.	1·3 E.
17 ...	3·4 W.	12·5 W.	5·6 W.	1·3 E.
18 ...	10·3 W.	13·4 W.	1·3 W.	3·0 E.
19 ...	11·6 W.	10·8 W.	1·7 E.	4·3 E.
20 ...	9·5 W.	4·7 W.	0·9 E.	4·7 E.
21 ...	0·9 W.	4·7 E.	1·3 E.	6·0 E.
22 ...	6·9 E.	9·9 E.	1·7 E.	8·2 E.
23 ...	12·9 E.	8·6 E.	3·4 E.	10·3 E.

31. Treating these numbers in the manner described in paragraph 8 of the preceding paper, the inequalities for the solar astronomical hours 0 to 23, in order, of the typical variation $f_{c2}(h)$ for the whole year were found to be as follows :—

$$
\begin{array}{l}
+16·7\,;\ +12·0\,;\ +5·2\,;\ -1·5\,;\ -5·5\,;\ -5·1\,;\\
-\ 2·9\,;\ -\ 1·2\,;\ -1·5\,;\ -0·5\,;\ -0·6\,;\ +0·7\,;\\
+\ 0·7\,;\ +\ 0·7\,;\ +0·4\,;\ +0·9\,;\ -1·2\,;\ -3·6\,;\\
-\ 6·6\,;\ -11·0\,;\ -9·8\,;\ -4·0\,;\ +5·6\,;\ +14·2\,;
\end{array}
$$

where the signs indicate movements of the north end of the declination magnet + towards the east and − towards the west.

The factor used for converting these numbers into C. G. S. units of force was ·00000178 = 0·36737 × ·000004848, or the product of the horizontal force at Batavia (in C. G. S. units) multiplied by the arc of 1″; and the mean value, for the seven years, of the horizontal force was obtained from data given (in British units) on page 193* of the volume of

the Batavia Observations referred to above. The inequalities of the converted variation, in the same order, are :—

+·000030 ; +·000021 ; +·000009 ; −·000003 ; −·000010 ; −·000009 ;
−·000005 ; −·000002 : −·000003 ; −·000001 ; −·000001 ; +·000001 ;
+·000001 ; +·000001 ; +·000001 ; +·000002 ; −·000002 ; −·000006 ;
−·000012 ; −·000020 ; −·000017 ; −·000007 ; +·000010 ; +·000025 ;

32. For comparison with this variation the similar typical variation ($f_{c2}(h)$ for the full year) have been calculated, for Bombay, from the numbers in the 8th and 15th columns of Tables 1 to 4 of the preceding paper, and for Trevandrum, from the means of the numbers in all the columns of each of Tables XXXVII to XL of Volume I of the Trevandrum Magnetical Observations. The results found—the inequalities for the solar astronomical hours from 0 to 23, in order, for Bombay were :—

−·000003 ; −·000003 ; +·000002 ; +·000004 ; +·000005 ; +·000003 ;
−·000001 ; −·000002 ; −·000002 ; ·000000 ; −·000001 ; +·000001 ;
+·000002 ; +·000002 ; +·000002 ; +·000002 ; ·000000 ; +·000001 ;
·000000 ; +·000004 ; ·000000 ; −·000005 ; −·000005 ; −·000005 ;

and the inequalities for twenty-fifths of the mean solar day from 0 to 24, in order, for Trevandrum were :—

+·000005 ; +·000002 ; −·000002 ; −·000005 ; −·000006 ; −·000005 ;
−·000004 ; −·000003 ; −·000002 ; −·000001 ; ·000000 ; +·000002 ;
+·000003 ; +·000004 ; +·000004 ; +·000003 ; +·000001 ; −·000001 ;
−·000003 ; −·000004 ; −·000003 ; −·000001 ; +·000003 ; +·000006 ; +·000007.

The curves of Figs. 70 to 72 have been constructed to represent this variation ($f_{c2}(h)$ for the full year) for the places Bombay, Trevandrum and Batavia in order; and remarking that the respective amounts of the magnetic dip at these places are about 19° N., 3° S. and 27° S., and that there is a similar progression of change in the three curves, that of Bombay vanishing and becoming inverted when we pass southward to Trevandrum, and that of Trevandrum increasing in range whilst retaining the inverted form in passing still further south to Batavia, we may look upon the three curves as being, in their principal features and subject to growth of range, of a single type. This element of the luni-solar variation is similar, in this respect, to the mean solar diurnal variation of declination for the full year, which also is, in its principal features, and except in high latitudes, of a single type, and becomes inverted in passing from north to south magnetic latitudes. But similarity of growth in these variations is not confined to change with change of latitude of the mean variations for the full year, but extends also, as will appear on consideration of the curves of Figs. 1 to 4 and 17 to 21 of the preceding paper, to change with change of season ; for, excluding from view regions of high magnetic latitude, it is a well-known *general* characteristic of the solar diurnal variation that it acquires more of the north magnetic latitude character* as the sun advances northward in declination, and more of the south magnetic latitude character* as the sun advances southward, whether the station of observation be north or south of the magnetic equator ; and this holds also in the growth with change of season of the typical variation curves referred to of both the stations Bombay and Trevandrum ; that is to say the winter curves (Figs. 1 and 17) of Bombay and Trevandrum are both of the south latitude character, whilst the summer curves (Figs. 3 and 19 or 20) are both of the north latitude character, and there is progressive change from one to the other and onward to the original phase of the cycle of change.

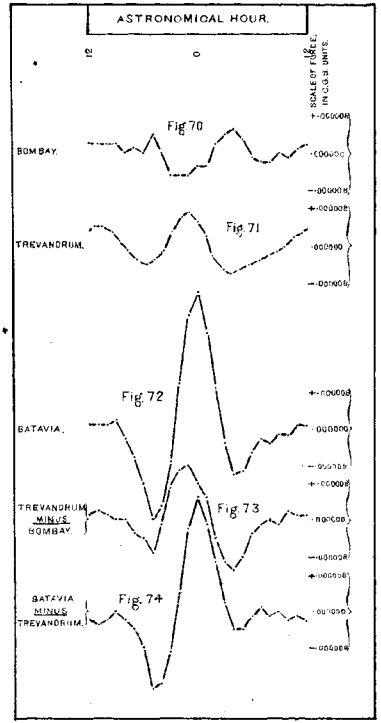
33. Herein we find further reason than was stated in paragraph 7 of the preceding paper for regarding the so-called lunar diurnal variations as being, when properly interpreted, parts only of the solar diurnal variations ; and a presumption is raised that the typical variations and the regular solar diurnal variations originate in one and the same solar magnetic action on the earth. Or, to put the latter point more clearly, if the total solar diurnal variation at any season of the year be respresented by

$$F(h)+f_{c2}(h)\ \omega_{t\,2}\,\frac{\pi}{p}\,t+\&c.,$$

where $F(h)$ represents the average solar diurnal variation for a ful lunation, then $F(h)$ and $f_{c2}(h)$ vary in the same manner with the season of the year. It thus becomes an inquiry of interest whether the indications of the typical variation curves of Bombay and Trevandrum are borne out by the results of similar investigations for stations of not high latitude in other parts of the world.

* By north or south magnetic latitude character is here meant the character which the solar diurnal variation has, on the average of the full year, at stations of north or south magnetic latitude respectively—the south latitude character being a simple inversion of the north latitude character.

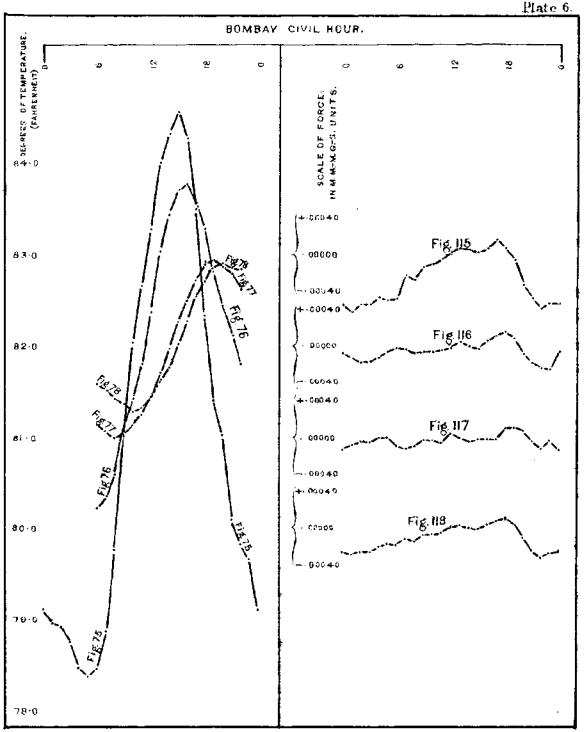
TYPICAL VARIATION $[\delta_{\alpha s}{}^{(h)}]$ OF DECLINATION FOR FULLYEAR.



FIGURES 70 TO 72:—SEE PARAGRAPH 32.
" 73 AND 74:— " " 34

INFLUENCE OF TEMPERATURE ON THE BIFILAR MAGNETOMETER.

Plate 6.



FIGURES 75 TO 78:— SEE PARAGRAPH 42.
" 115 TO 118:— " " 49.

DRAWN ON STONE AND LITHO GOVT. PHOTOZINCO OFFICE POONA 1868.

34. The curves of Figs. 73 and 74 have been constructed to represent the growth of the typical variation $f_{c2}(h)$ for the full year between Bombay and Trevandrum and between Trevandrum and Batavia respectively; that is, their ordinates are the excesses of the inequalities of the more southern station over those of the more northern station: it will be observed that these difference-curves are also similar in their principal features, and have ranges that are roughly proportional to the respective differences of latitude 10° and 15°. It should be remarked, however, that a part of the excess range of the Batavia curve (Fig. 72) is due to the fact that only three days in a lunation were classed as belonging to each quarter, whereas at Bombay four days were so classed and at Trevandrum seven or eight days. The geographical latitudes of Bombay, Trevandrum and Batavia are, it may be mentioned, 18° 54′ N; 8° 31′ N; and 6° 11′ S. respectively.

35. In the Report of the British Association, 1886, pages 84 to 97, the writer of these pages has described a modification of Sabine's method of analysing a body of hourly magnetic observations, which has shown its capability of eliciting a fair knowledge of the typical variation elements of the luni-solar variations of declination and horizontal force from the observations of only a single winter quarter of the year; and, in a later communication to the meeting of Association held at Manchester this year, he has applied the method to a single quarter's observations of the vertical force at Bombay, and has obtained results of a character in general accord with those for declination and horizontal force of the preceding paper.

APPENDIX III.

On the Influence of Temperature upon the Bifilar Magnetometer.

36. Three principal methods have been adopted by magneticians for determining what is called the temperature coefficient of the bifilar magnetometer, and in each method the assumptions are made (1) that the change of scale-reading of the magnetometer due to change of temperature of the instrument is proportional to the latter change, and (2) that the reading of a correct thermometer whose bulb is exposed to the air of the magnetometer box indicates correctly the simultaneous temperature of the instrument. In the first method the magnet is detached and its own temperature coefficient is separately determined by hot and cold water experiments, and with this and the expansion coefficients of the suspension wire and pulley as data, an expression for the temperature coefficient of the instrument is easily found by means of its equilibrium formula. It is, however, objectionable to break the continuity of a series of observations by thus detaching the magnet and performing upon it operations that will probably alter its strength permanently. In the second method the instrument and its surrounding atmosphere are artificially heated and cooled, and the effect on the scale-reading is directly observed: in this case the changes of horizontal force that occur during the experiments are sometimes eliminated by means of simultaneous observations of a subsidiary bifilar magnetometer which is kept as nearly as possible at a constant temperature. The third method is to compare the aggregate, in a long period, of changes of mean daily temperature from day to day with the aggregate of corresponding changes from day to day of the mean daily scale reading of the magnetometer. The first method was that which was embodied in the instructions of the Committee of Physics of the Royal Society (in 1841); the second has been used, amongst other places, at Greenwich, Makerstoun, Toronto, the Parc St. Maur and Colába; and the third was first used by the late John Allan Broun. The Committee of Physics remark upon the second method that "there must remain much uncertainty as to the true temperature of the magnet-bar, owing to the length of time necessary to enable it to assume the temperature of the surrounding air and the difficulty of maintaining that temperature uniform."

37. The second and third methods have both been used to find the temperature coefficient of Grubb's horizontal force magnetometer at the Colába Observatory, and, care having been taken in turning to account the heating and cooling experiments to make use only of scale readings for times when the magnet had acquired a steady high or low temperature, and not of such as accompanied a rapid rise or fall of temperature, each of the two methods gives results which are consistent among themselves and consistent with the results of the other method. The object of this paper is, whilst calling attention to this consistency—which implies that the horizontal force is not a function of the natural temperature of the station of observation as shown in its variation from day to day—to show that the assumption of simultaneity of movement of the temperatures of the magnet and thermometer is yet far from being borne out by observation.

38. Throughout the year 1872 hourly records and continuous registrations were obtained at Colába of Grubb's horizontal force magnetometer and of the horizontal force magnetograph respectively, and the latter of these instruments being in an underground room which is subject to a diurnal range of temperature of less than half a degree Fahrenheit, its registrations on any day may be taken, without considerable relative error as between one hour's ordinate and another's, to be free from the influence of variation of temperature; and thus a comparison of the monthly mean values of the diurnal variations of horizontal force yielded by the two instruments will afford a measure of the influence of diurnal temperature changes upon the former instrument; this is, of course, on the assumption that the diurnal variation of horizontal force is the same at the places occupied by the two instruments, an assumption which is supported by the fact that the general range of the difference between the two variations in the different months is roughly proportional to the range of the temperature variation.

39. For evidence in support of the statements that have been made, reference may now be made to the Appendices to the Bombay Magnetical and Meteorological Observations, 1879-82, in which detailed accounts will be found both of the heating and cooling experiments and of the modification of the third method adopted at Colába for determining the temperature coefficient from the regular observations. From Table 89 page [159], we find that the intervals allowed for the magnet of Grubb's horizontal force magnetometer to

acquire the temperature of the surrounding air after the commencement of the successive heatings and coolings, and the temperature coefficients yielded by the successive pairs of differences of thermometer readings and differences of scale-readings were as follows:—

TABLE 34.

Grubb's Horizontal Force Magnetometer.	Interval.	Temperature Co-efficient in excess of ·1506.	Means.
	h m		
Cold ...			
Hot ...	7 58	−·008	
Cold ...	12 0	−·014	
Cold ...			
Hot ...	7 30	+·003	
Cold ...	12 0	−·005	−·008
Hot ...	8 5	−·011	
Cold ...	12 0	−·009	
Hot ...	7 30	−·011	
Cold ...	12 0	−·011	
Cold ...			
Hot ...	6 20	+·004	
Cold ...	20 8		+·004
Cold ...			
Hot ...	15 32	+·004	
Cold ...	15 17		

And adding the mean of the two results (−·008 and +·004) to ·1506 the final value of the coefficient gven by these experiments is found to be ·1486, or the effect upon the instrument of a rise of one degree of temperature is equivalent to the effect of a decrease of the horizontal force of (·1486 × ·00574 =) ·000853 m. m.—m. g.—s. units.

40. On pages [154] and [155] the results of the application of the third method to the observations of the years beginning with the 1st November from 1856 to 1864 are found to be as follows:—

TABLE 35.

Year.	$\frac{\Sigma(\Delta x)}{\Sigma(\Delta t)}$.
1856	·1527
1857	·1403
1858	·1585
1859	·1356
1860	·1711
1861	·1477
1862	·1536
1863	·1417
1864	·1544
Mean =	·1506
Mean expressed in force =	·000843 *i.e.* (·1506 × ·00560)

This agrees as closely as could possibly be expected with the result (·000853) found by the experimental heatings and coolings, and similar agreement is found when the third method is applied to the observations of the years 1847 to 1850 and 1852 to 1855.

41. If, however, instead of subjecting the magnetometer to a high temperature for a considerable length of time and then to a low temperature for a similarly extended interval, the instrument is subjected to a periodical variation of temperature of short period, (as it is in actual use, the period being the solar day) it is well known that the phases of the variation of temperature of the magnet will be retarded, and the range of it contracted as compared with the variation of temperature of the external air, and especially so when, as at Colába, the magnetomter box is surrounded on its sides and at top by a cushion of quilted cotton two inches thick. The upper half of the bulb of the thermometer of the Colába instrument is enclosed in a hollow space in the lid of the box, without touching the lid, and the lower half is wholly below the lid; but even if the bulb were well within the box and in close proximity to the magnet*, the variation of temperature shown by the thermometer would be larger and in advance of that of the magnet, because the specific heat of the bulb is much less than that of the magnet: to test this, however, the following experiment was arranged. A large deal box divided into compartments of about one foot cube, and all the sides of each compartment of which were covered with woollen cloth thickly padded with tow, was supported on one of its sides at a convenient height in the small magnetic observatory, the door of which was kept closed: the box being closed, thermometers were passed through corks inserted in its uppermost side so that their bulbs should be in the middle of the several inner compartments and their scales be visible outside. The errors of the thermometers (numbered 5, 6 and 8) used in the experiments were practically constant throughout those parts of the scales that were read in the course of the experiments. The thermometers were similar in shape and had cylindrical bulbs about an inch long: the bulb of No. 5 was outside the box and exposed to the air of the closed room, that of No. 8 was exposed to the air of one of the padded compartments of the closed box, and that of No. 6 was similarly exposed in an adjoining compartment after practical enlargement by immersing it in mercury contained in a cylindrical iron vessel: the iron vessel was suspended by means of thin iron wires in the middle of the compartment, and the mercury was contained in a cylindrical aperture in it just large enough to admit the cylindrical bulb of the thermometer freely and to allow its middle point to occupy the middle point of the space surrounded by the outer surface of the iron cylinder: it was thus necessary, in the case of No. 6, that the mass of iron should be successively heated and cooled by radiation and by its contact with the air of the compartment before the thermometer could itself acquire the successive temperatures of the mass of iron. The iron cylinder weighed 18,350 grains, was 2·34 inches in height, and 2·28 inches in diameter, and the aperture in it was 1·90 inches long and 0·36 inch in diameter.

42. Hourly observations were made of the three thermometers from 6^h to 22^h on the 21st to 26th September 1885, and the six-day averages of them for each hour appear in the table below, in which are also entered the average tabulations, from 0^h to 23^h for the same six days, of the Colába Dry-bulb Thermograph:—

TABLE 36.

Thermometer No.	Hours of Colába Civil Time.											
	0	1	2	3	4	5	6	7	8	9	10	11
Thermograph dry-bulb. ...*a*	79·12	78·98	78·92	78·77	78·47	78·38	78·47	78·88	79·78	81·02	82·03	82·67
5 ...*b*							80·22	80·37	80·60	81·13	81·42	81·80
8 ...*b*							81·15	81·08	81·00	81·05	81·15	81·25
6 ...*b*							81·58	81·52	81·42	81·37	81·28	81·32

a Tabulations made for 2 minutes past the hour. *b* Readings taken at 3 minutes before the hour.

* A thermometer with its bulb so placed was read regularly every day, as well as the thermometer belonging to the instrument, at the hours 6, 10, 14, 16 and 22 during the months June to December 1884, when the box containing the magnetometer was covered with thick cushions and from January to December 1885 when the cushions had been removed and the box was exposed to the air of the room. On the average of the two periods the excesses of the readings of the ordinary thermometer over those of the one with its bulb in the middle of the box had, at the five hours named, the relative values ·00; ·00; ·04; ·06; ·02 and ·00; ·27; ·51; ·47; ·09 respectively. It will be seen from the former set of numbers and from the conclusions reached in paragraph 49 that but little of the discrepancies that form the subject of this inquiry arises from the faulty placing of the thermometer; but it may be inferred from the second set of numbers that errors arising from this cause are far from being negligible when the box of the instrument is exposed directly to the air of the room. It should be mentioned that from 1879·01 to 1885·00 an inner room of bámboo matting was erected about the horizontal force magnetometer, and formed a protection additional to the cushions covering the box of the instrument.

TABLE 36—*continued.*

Thermometer No.	HOURS OF COLÁBA CIVIL TIME.											
	12	13	14	15	16	17	18	19	20	21	22	23
Thermograph dry-bulb. ...*a*	83·27	84·00	84·32	84·58	84·28	83·43	82·35	81·40	81·03	80·10	79·82	79·67
5 ...*b*	82·37	83·03	83·43	83·70	83·77	83·52	83·28	82·82	82·45	82·13	81·80	
8 ...*b*	81·45	81·70	81·98	82·28	82·50	82·72	82·90	82·95	82·88	82·80	82·63	
6 ...*b*	81·45	81·63	81·77	82·02	82·28	82·55	82·73	82·87	82·93	82·88	82·85	

a Tabulations made for 2 minutes past the hour. *b* Readings taken at 3 minutes before the hour.

These numbers are graphically displayed in Figs. 75 to 78. They show degradation of range and retardation of phase as between the atmosphere (Fig. 75) and the air of the room (Fig. 76), and again as between the air of the room and that of a compartment in the box (Fig. 77 or Fig. 78); and they show, further, degradation and retardation as between a compartment occupied by a thermometer with a small bulb (Fig. 77), and a similar compartment occupied by a thermometer with a bulb of largely increased capacity for heat (Fig. 78).

43. On page [238] of the Appendices appears a Table (163) showing the mean diurnal variation of horizontal force for each month of the year 1872: these variations are derived from the readings of Grubb's horizontal force magnetometer after correction for temperature at the rate of +0·15 scale division (equivalent to ·000823 in force) for each increase of a degree of temperature. On page [241] appears also a Table (165) showing the diurnal variation of the readings of the thermometer of Grubb's horizontal force magnetometer for each month of the year 1872. By means of these two Tables may be found the diurnal variation of the scale readings—converted into force—of Grubb's horizontal force magnetometer *uncorrected for temperature:* all that is necessary is to multiply the numbers in the temperature variation table (Table 165) by —·000823, and then add corresponding numbers in the converted table and Table 163: but the process was actually applied to similar tables from which the days of no magnetograph record, as shown in the foot note to the next paragraph, were excluded, and the results are shown in the following table:—

TABLE 37.—*Showing the mean diurnal variation of horizontal force as derived from the scale-readings of Grubb's horizontal force magnetometer when the scale-readings are* uncorrected *for temperature.*

1872.	MONTH.											
Bombay Civil Time.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
h. m.												
0 14	—·00233	—·00189	—·00209	—·00254	—·00205	—·00180	—·00176	—·00181	—·00201	—·00225	—·00183	—·00204
1 14	—·00180	—·00161	—·00184	—·00243	—·00190	—·00132	—·00202	—·00179	—·00173	—·00180	—·00141	—·00187
2 14	—·00131	—·00165	—·00184	—·00213	—·00176	—·00147	—·00185	—·00179	—·00138	—·00145	—·00119	—·00111
3 14	—·00137	—·00132	—·00137	—·00192	—·00143	—·00161	—·00203	—·00168	—·00116	—·00110	—·00101	—·00112
4 14	—·00084	—·00085	—·00121	—·00178	—·00133	—·00149	—·00173	—·00159	—·00106	—·00068	—·00075	—·00080
5 14	—·00069	—·00062	—·00082	—·00146	—·00104	—·00139	—·00134	—·00142	—·00112	—·00031	—·00038	—·00056
6 14	—·00006	+ ·00002	—·00073	—·00083	—·00052	—·00081	—·00068	—·00105	—·00118	—·00022	+ ·00014	+ ·00004
7 14	+ ·00116	+ ·00123	+ ·00010	—·00019	+ ·00073	+ ·00035	+ ·00061	—·00006	—·00098	+ ·00014	+ ·00125	+ ·00075
8 14	+ ·00227	+ ·00281	+ ·00184	+ ·00182	+ ·00253	+ ·00163	+ ·00235	+ ·00126	+ ·00037	+ ·00139	+ ·00240	+ ·00162
9 14	+ ·00345	+ ·00421	+ ·00370	+ ·00415	+ ·00445	+ ·00292	+ ·00404	+ ·00270	+ ·00251	+ ·00334	+ ·00402	+ ·00298
10 14	+ ·00448	+ ·00489	+ ·00513	+ ·00585	+ ·00549	+ ·00420	+ ·00442	+ ·00418	+ ·00422	+ ·00458	+ ·00499	+ ·00417
11 14	+ ·00477	+ ·00501	+ ·00572	+ ·00611	+ ·00553	+ ·00445	+ ·00427	+ ·00449	+ ·00483	+ ·00527	+ ·00537	+ ·00432
12 14	+ ·00434	+ ·00434	+ ·00488	+ ·00503	+ ·00473	+ ·00414	+ ·00396	+ ·00408	+ ·00448	+ ·00438	+ ·00444	+ ·00376
13 14	+ ·00299	+ ·00294	+ ·00371	+ ·00389	+ ·00328	+ ·00317	+ ·00281	+ ·00312	+ ·00365	+ ·00260	+ ·00276	+ ·00251
14 14	+ ·00152	+ ·00082	+ ·00200	+ ·00187	+ ·00160	+ ·00168	+ ·00165	+ ·00181	+ ·00218	+ ·00097	+ ·00117	+ ·00149
15 14	+ ·00022	—·00048	+ ·00033	+ ·00025	—·00007	+ ·00040	+ ·00058	+ ·00044	+ ·00068	—·00032	—·00024	+ ·00042
16 14	—·00069	—·00134	—·00054	—·00097	—·00114	—·00086	—·00065	—·00054	—·00017	—·00123	—·00163	—·00065
17 14	—·00118	—·00189	—·00159	—·00144	—·00169	—·00159	—·00148	—·00114	—·00072	—·00160	—·00209	—·00112
18 14	—·00147	—·00207	—·00219	—·00160	—·00212	—·00176	—·00186	—·00132	—·00128	—·00129	—·00211	—·00131
19 14	—·00173	—·00231	—·00246	—·00187	—·00220	—·00150	—·00209	—·00164	—·00186	—·00187	—·00261	—·00162
20 14	—·00248	—·00245	—·00268	—·00235	—·00257	—·00167	—·00207	—·00170	—·00185	—·00233	—·00321	—·00217
21 14	—·00304	—·00267	—·00264	—·00235	—·00288	—·00177	—·00201	—·00181	—·00194	—·00216	—·00318	—·00261
22 14	—·00315	—·00272	—·00279	—·00245	—·00290	—·00197	—·00167	—·00157	—·00227	—·00216	—·00269	—·00266
23 14	—·00275	—·00249	—·00266	—·00272	—·00272	—·00185	—·00157	—·00129	—·00224	—·00180	—·00219	—·00238

44. Again, on page [206] of the Appendices is found a table (137) showing the diurnal variation of horizontal force for each month of the year 1872 derived from the registrations of the Colába horizontal force magnetograph: but for comparison with the magnetometer variations of Table 37 it was necessary to recalculate these—omitting days

(Sundays and holidays) on which the magnetometer was not observed*: the variations thus found were also corrected for progressive decrease of the registrations from beginning to end of each month, and further for five minutes' growth of the diurnal variation of horizontal force between the time of reading the magnetometer (14 minutes past the hour) and the time for which the registrations of the magnetograph were tabulated (19 minutes past the hour). The magnetograph variations, thus corrected, are entered in the next table :—

TABLE 38.—*Showing the diurnal variation of horizontal force for each month of the year 1872, derived from the registrations of the Colába horizontal force magnetograph.*

1872.	MONTH.											
Colába Civil Time.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
h. m.												
0 14	—·00164	—·00155	—·00204	—·00246	—·00207	—·00164	—·00178	—·00155	—·00215	—·00194	—·00146	—·00180
1 14	—·00125	—·00137	—·00180	—·00221	—·00190	—·00129	—·00197	—·00185	—·00175	—·00171	—·00115	—·00172
2 14	—·00124	—·00151	—·00188	—·00194	—·00196	—·00147	—·00189	—·00181	—·00146	—·00151	—·00118	—·00120
3 14	—·00110	—·00124	—·00142	—·00187	—·00162	—·00151	—·00222	—·00180	—·00123	—·00140	—·00123	—·00122
4 14	—·00091	—·00106	—·00132	—·00180	—·00166	—·00157	—·00197	—·00174	—·00124	—·00115	—·00106	—·00097
5 14	—·00076	—·00083	—·00107	—·00166	—·00151	—·00155	—·00148	—·00165	—·00130	—·00103	—·00096	—·00082
6 14	—·00037	—·00017	—·00119	—·00133	—·00095	—·00107	—·00062	—·00120	—·00125	—·00101	—·00059	—·00049
7 14	+·00020	+·00038	—·00055	—·00071	+·00034	+·00007	+·00050	—·00018	—·00112	—·00068	—·00027	+·00010
8 14	+·00103	+·00155	+·00094	+·00130	+·00196	+·00145	+·00220	+·00099	+·00015	+·00080	+·00160	+·00106
9 14	+·00215	+·00271	+·00279	+·00352	+·00392	+·00259	+·00382	+·00224	+·00221	+·00269	+·00285	+·00220
10 14	+·00307	+·00356	+·00451	+·00519	+·00499	+·00385	+·00423	+·00374	+·00388	+·00391	+·00398	+·00333
11 14	+·00368	+·00412	+·00536	+·00561	+·00516	+·00425	+·00413	+·00424	+·00453	+·00481	+·00435	+·00381
12 14	+·00358	+·00372	+·00482	+·00468	+·00450	+·00395	+·00375	+·00394	+·00448	+·00408	+·00377	+·00336
13 14	+·00263	+·00254	+·00381	+·00362	+·00325	+·00314	+·00278	+·00322	+·00366	+·00262	+·00243	+·00240
14 14	+·00147	+·00089	+·00237	+·00199	+·00178	+·00179	+·00184	+·00201	+·00237	+·00122	+·00123	+·00151
15 14	+·00047	—·00006	+·00087	+·00063	+·00036	+·00062	+·00072	+·00068	+·00099	+·00018	+·00025	+·00078
16 14	—·00032	—·00075	—·00004	—·00045	—·00051	—·00056	—·00041	—·00026	+·00012	—·00062	—·00072	—·00008
17 14	—·00080	—·00097	—·00124	—·00090	—·00101	—·00122	—·00122	—·00079	—·00041	—·00091	—·00114	—·00081
18 14	—·00091	—·00139	—·00181	—·00118	—·00160	—·00148	—·00168	—·00105	—·00101	—·00076	—·00116	—·00078
19 14	—·00114	—·00160	—·00213	—·00145	—·00179	—·00136	—·00189	—·00128	—·00167	—·00127	—·00177	—·00115
20 14	—·00166	—·00163	—·00226	—·00203	—·00222	—·00148	—·00198	—·00149	—·00171	—·00170	—·00229	—·00160
21 14	—·00213	—·00184	—·00221	—·00191	—·00255	—·00170	—·00173	—·00168	—·00186	—·00167	—·00225	—·00206
22 14	—·00223	—·00186	—·00231	—·00228	—·00252	—·00182	—·00162	—·00142	—·00208	—·00161	—·00199	—·00203
23 14	—·00190	—·00174	—·00219	—·00249	—·00249	—·00191	—·00163	—·00125	—·00209	—·00144	—·00180	—·00207

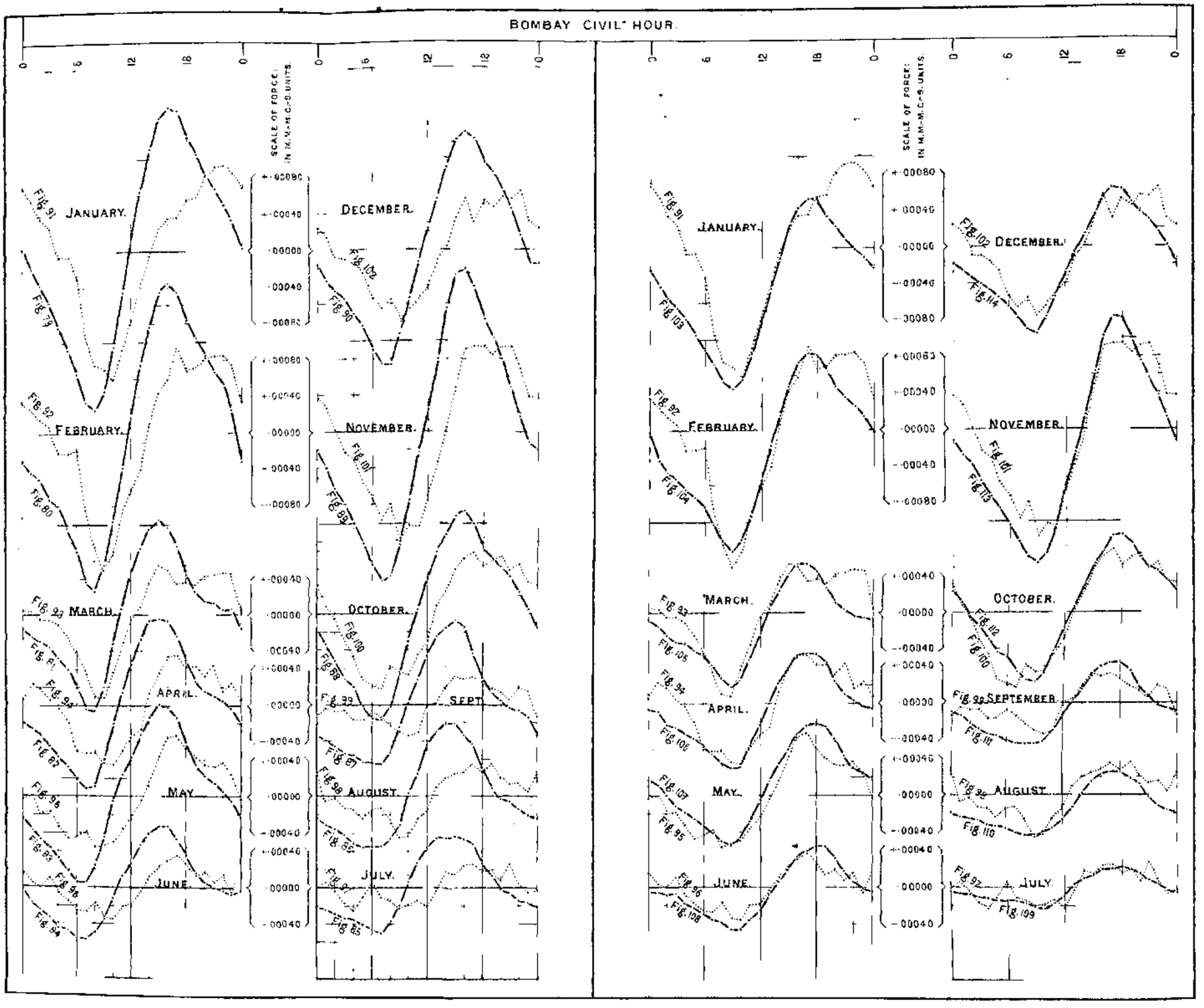
And now substracting the numbers of Table 38 from corresponding numbers of Table 37 we obtain the following table of excesses of the one set of numbers over the other set :—

TABLE 39.—*Excesses of the hourly inequalities of horizontal force as shown by Grubb's horizontal force magnetometer, when no correction for temperature is applied to the scale-readings, and the same as shown by the Colába horizontal force magnetograph.*

1872.	MONTH.											
Bombay Civil Time.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
h. m.												
0 14	—·00069	—·00034	—·00005	—·00008	+·00002	—·00016	+·00002	—·00026	+·00014	—·00031	—·00037	—·00024
1 14	—·00055	—·00024	—·00004	—·00022	·00000	—·00003	—·00005	+·00006	+·00002	—·00009	—·00026	—·00015
2 14	—·00037	—·00014	+·00004	—·00019	+·00020	·00000	+·00004	+·00002	+·00008	+·00006	—·00001	+·00009
3 14	—·00027	—·00008	+·00005	—·00005	+·00019	—·00010	+·00019	+·00012	+·00007	+·00030	+·00022	+·00010
4 14	+·00007	+·00021	+·00011	+·00002	+·00033	+·00008	+·00024	+·00015	+·00018	+·00047	+·00031	+·00017
5 14	+·00007	+·00021	+·00025	+·00020	+·00047	+·00016	+·00011	+·00023	+·00018	+·00072	+·00058	+·00026
6 4	+·00031	+·00019	+·00046	+·00050	+·00043	+·00026	—·00006	+·00015	+·00007	+·00079	+·00073	+·00053
7 14	+·00096	+·00085	+·00065	+·00052	+·00039	+·00028	+·00011	+·00012	+·00014	+·00082	+·00098	+·00065
8 14	+·00124	+·00126	+·00090	+·00052	+·00057	+·00018	+·00015	+·00027	+·00022	+·00059	+·00080	+·00056
9 14	+·00130	+·00150	+·00091	+·00063	+·00053	+·00033	+·00022	+·00046	+·00030	+·00065	+·00117	+·00078
10 14	+·00141	+·00133	+·00062	+·00066	+·00050	+·00035	+·00019	+·00044	+·00034	+·00067	+·00101	+·00064
11 14	+·00109	+·00089	+·00036	+·00050	+·00037	+·00020	+·00014	+·00025	+·00030	+·00046	+·00102	+·00051
12 14	+·00076	+·00062	+·00006	+·00035	+·00023	+·00019	+·00021	+·00014	·00000	+·00030	+·00067	+·00040
13 14	+·00036	+·00040	—·00010	+·00027	+·00003	+·00003	+·00003	—·00010	—·00001	—·00002	+·00033	+·00011
14 14	+·00025	—·00007	—·00037	—·00012	—·00018	—·00011	—·00019	—·00020	—·00019	—·00025	—·00006	—·00002
15 14	—·00025	—·00042	—·00054	—·00038	—·00043	—·00022	—·00014	—·00024	—·00031	—·00050	—·00049	—·00036
16 14	—·00037	—·00059	—·00050	—·00052	—·00063	—·00030	—·00024	—·00028	—·00029	—·00061	—·00091	—·00057
17 14	—·00038	—·00092	—·00035	—·00054	—·00068	—·00037	—·00026	—·00035	—·00031	—·00069	—·00095	—·00031
18 14	—·00056	—·00068	—·00038	—·00042	—·00052	—·00028	—·00018	—·00027	—·00027	—·00053	—·00095	—·00053
19 14	—·00059	—·00071	—·00033	—·00042	—·00041	—·00014	—·00020	—·00036	—·00019	—·00060	—·00084	—·00047
20 14	—·00082	—·00082	—·00042	—·00032	—·00035	—·00019	—·00009	—·00021	—·00014	—·00063	—·00092	—·00057
21 14	—·00091	—·00083	—·00043	—·00044	—·00033	—·00007	—·00028	—·00013	—·00008	—·00049	—·00093	—·00055
22 14	—·00092	—·00086	—·00048	—·00017	—·00038	—·00015	—·00005	—·00015	—·00019	—·00055	—·00070	—·00063
23 14	—·00085	—·00075	—·00047	—·00023	—·00023	+·00006	+·00006	—·00004	—·00015	—·00036	—·00039	—·00031

* In like manner the Tables (163 and 165) referred to in the last paragraph were also modified by the omission of ten days—one in January, six in February and three in October—for which no comparable simultaneous record was obtained from the horizontal force magnetograph.

INFLUENCE OF TEMPERATURE ON THE BIFILAR MAGNETOMETER.



FIGURES 79 TO 102:— SEE PARAGRAPH 44.

Figs. 79 to 90 are constructed to represent for each month the (slightly modified) numbers of Table 165—the diurnal variations of the readings of the thermometer of Grubb's horizontal force magnetometer, converted at the rate of ·000823 per degree into m. m.—m. g.—s. units of force; and on the same forms, but with inverted scales, are curved the variations of Table 39 forming Figs. 91 to 102.

45. If the diurnal variations of horizontal force at the places of the two instruments were the same, and the thermometer of Grubb's horizontal force magnetometer always indicated correctly the temperature of the instrument, these two sets of curves ought, in each month, to coincide. They have, in fact, such a degree of similarity as leaves no doubt that the greater parts of the excess force variations are due to variations of the temperature of the magnetometer.* But the phases of the curves of the excess force variations systematically lag behind, and the ranges of the curves are smaller than those of the thermometer variations; and these relations are most marked in summer, when the range of temperature of the instrument is least, and least so in winter, when the range of temperature is greatest. Another striking feature of the two sets of curves is that in the fair weather months, October to May, the upward inflexion of the (inverted) excess force curve is extended much further into the night than the corresponding temperature inflexion in the thermometer curve, whilst in the gloomy months, June to September, the two sets of curves are more nearly similar in form as well in the evening as in the rest of the day.

46. As a general rule, the light which illuminates the scale of Grubb's horizontal force magnetometer was kept burning during the monsoon night and day, whilst during the dry months it was lighted in the evening and put out in the morning; and Mr. F. Chambers, who had previously constructed and studied these curves, makes the happy suggestion, that the late continuance of the upward inflexion of the excess force variation curves from October to May is due to the heating of the magnetometer by the heat rays reflected upon it, but not upon the thermometer, from the lamp; whilst the absence of the same feature in the monsoon curves is explained by the heating action of the lamp having been, at that season, practically constant all through the day.

47. On the assumption that the rapid uprising at a nearly uniform rate of the (inverted) excess force variation curve from morning to afternoon represented a parallel phenomenon dependent on the corresponding uprising of the thermometer variation curve, an endeavour has been made to evaluate, for each month, the ratio of the amounts of the two movements and the extent of the interval of time separating corresponding phases of the two curves. This was done by re-constructing the curves on a large scale and drawing tangent lines through the straight parts referred to: the tangents of the inclination of these lines to the time scale were measured, and the ratios of these tangents taken as the ratios required: also the middle points of the tangents to the straight parts of the two curves being regarded as corresponding points, the interval of time separating them was taken as the interval required. The results were as follows:—

TABLE 40.

1872.	Ratio of excess force change to thermometer change.	Lagging of phase of excess force variation behind phase of thermometer variation.	Range of thermometer variation.
		Hours.	°
January	·637	0·87	4·08
February	·632	1·50	4·13
March	·680	1·02	2·56
April	·649	2·15	2·27
May	·706	3·08	2·38
June	·699	2·40	1·54
July	·406	3·13	1·30
August	·523	2·38	1·66
September	·598	2·73	1·91
October	·714	2·08	2·79
November	·792	1·85	4·15
December	·630	1·40	3·09

* After this, paragraph 274 of the Appendices for 1879—82, where a different conclusion was reached, must be understood to be withdrawn.

48. It was anticipated that these numbers might indicate some empirical relationship between the two sets of phenomena that would admit of the elimination of the effects of natural temperature variation from the excess force variations, and thus allow of a separate exhibition of the artificial temperature variation effects; on curving them it was seen, however, that they have too unsteady a variation from month to month to be suited for such a use in their present rough state; smoothing was therefore effected—of the ratios by the method of least squares, on the assumption of a uniform rate of variation from December to June and a different uniform rate of variation from July to November, and of the intervals of lagging by assuming that they oscillated in a simple wave in the course of the year. The numbers then became:—

TABLE 41.

1872.	Ratio.	Lagging.	Range of thermometer variation.
		Hours.	°
January	·636	1·16	4·08
February	·649	1·26	4·13
March	·662	1·57	2·56
April	·675	2·00	2·27
May	·687	2·45	2·38
June	·700	2·80	1·54
July	·414	2·94	1·30
August	·510	2·84	1·66
September	·601	2·53	1·91
October	·703	2·10	2·79
November	·799	1·65	4·15
December	·623	1·30	3·09

49. With these numbers the elimination was effected for each month by first multiplying the thermometer variation, expressed in force, by the ratio, then lowering or raising the whole series of inequalities, so that the corresponding points of paragraph 47 should be represented by the same number in the contracted thermometer variation as in the excess force variation, and lastly by deducting the result, shifted onward by the amount of the lagging, from the excess force variation of that month. The residual force variation that remains after the elimination is shown, for each month and for certain combinations of months, in Table 42:—

TABLE 42.—*Residual diurnal variation of horizontal force found after an approximate elimination of temperature variation effects.*

1872.	HOURS OF COLABA CIVIL TIME.											
	0	1	2	3	4	5	6	7	8	9	10	11
January ...	−·00092	−·00096	−·00092	−·00094	−·00072	−·00088	−·00080	−·00031	−·00024	−·00026	−·00003	−·00007
February ...	−·00035	−·00056	−·00061	−·00060	−·00043	−·00051	−·00065	−·00016	+·00005	+·00018	+·00013	−·00004
March... ...	−·00014	−·00019	−·00022	−·00026	−·00024	−·00016	−·00002	+·00006	+·00018	+·00009	−·00014	−·00016
April	−·00014	−·00032	−·00041	−·00032	−·00030	−·00019	+·00002	+·00003	−·00012	−·00007	−·00003	+·00001
May	+·00020	+·00011	+·00020	+·00008	+·00014	+·00021	+·00010	−·00002	+·00007	−·00001	+·00003	+·00008
June	−·00020	−·00009	−·00009	−·00018	−·00019	−·00006	−·00003	−·00008	−·00021	−·00012	−·00009	−·00017
July	+·00003	−·00013	−·00005	+·00008	+·00012	−·00003	−·00022	−·00005	−·00004	+·00001	−·00004	−·00004
August ...	−·00046	−·00017	−·00024	−·00016	−·00016	−·00011	−·00022	+·00029	−·00017	+·00002	+·00001	−·00012
September ...	+·00004	−·00012	−·00014	−·00022	−·00015	−·00019	−·00033	−·00028	−·00022	−·00015	−·00008	·00000
October ...	−·00007	+·00002	+·00002	+·00013	+·00017	+·00029	+·00030	+·00018	−·00015	−·00012	+·00001	+·00004
November ...	−·00048	−·00054	−·00040	−·00033	−·00041	−·00029	−·00030	−·00023	−·00059	−·00029	−·00032	·00000
December ...	−·00043	−·00041	−·00024	−·00030	−·00030	−·00030	−·00012	−·00014	−·00034	−·00015	−·00014	−·00003
November to February ...	−·00054	−·00062	−·00054	−·00054	−·00046	−·00049	−·00047	−·00021	−·00028	−·00013	−·00009	−·00003
March, April, September and October ...	−·00008	−·00015	−·00019	−·00017	−·00013	−·00006	−·00001	−·00002	−·00008	−·00006	−·00006	−·00003
May to August, January to December ...	−·00012	−·00007	−·00004	−·00004	·00000	−·00000	−·00009	−·00011	−·00009	−·00002	−·00002	−·00006
	−·00025	−·00028	−·00026	−·00025	−·00020	−·00018	−·00019	−·00011	−·00015	−·00007	−·00006	−·00004

TABLE 42—*continued.*

1872.	HOURS OF COLABA CIVIL TIME.											
	12	13	14	15	16	17	18	19	20	21	22	23
January ...	−·00004	−·00009	−·00006	−·00004	+·00006	+·00016	−·00004	−·00026	−·00059	−·00082	−·00093	−·00096
February ...	+·00006	+·00021	+·00011	+·00007	+·00015	−·00008	+·00003	−·00007	−·00033	−·00046	−·00060	−·00059
March	−·00016	−·00007	−·00013	−·00012	+·00003	+·00019	+·00008	−·00004	−·00031	−·00041	−·00051	−·00054
April	+·00012	+·00027	+·00009	+·00001	+·00001	+·00002	+·00011	+·00002	−·00007	−·00034	−·00015	−·00025
May	+·00019	+·00021	+·00017	+·00007	+·00002	+·00008	+·00027	+·00034	+·00026	+·00010	−·00008	·00000
June	−·00007	−·00006	−·00004	−·00003	+·00002	+·00002	+·00016	+·00028	+·00012	+·00012	−·00009	+·00005
July	+·00022	+·00025	−·00009	+·00001	−·00004	−·00006	+·00004	·00000	+·00008	−·00019	−·00002	+·00004
August	−·00014	−·00022	−·00019	−·00009	−·00006	−·00009	−·00002	−·00017	−·00009	−·00014	−·00026	−·00020
September ...	−·00014	+·00001	−·00002	−·00001	+·00011	+·00014	+·00019	+·00016	+·00005	−·00002	−·00021	−·00021
October	+·00012	+·00005	+·00006	+·00003	+·00007	+·00013	+·00032	+·00017	−·00003	+·00001	−·00011	·00000
November ...	+·00003	+·00011	+·00011	+·00013	+·00010	+·00027	+·00026	+·00016	−·00017	−·00035	−·00032	−·00026
December ...	+·00011	+·00004	+·00011	−·00002	−·00003	+·00033	+·00008	+·00002	−·00018	−·00025	−·00046	−·00030
November to February ...	+·00004	+·00007	+·00007	+·00003	+·00007	+·00017	+·00008	−·00004	−·00032	−·00047	−·00058	−·00053
March, April, September and October ...	−·00001	+·00006	·00000	−·00002	+·00005	+·00012	+·00017	+·00008	−·00009	−·00019	−·00024	−·00025
May to August.	+·00005	·00000	−·00004	−·00001	−·00001	−·00001	+·00011	+·00011	+·00009	−·00003	−·00011	−·00003
January to December ...	+·00002	+·00004	+·00001	·00000	+·00004	+·00009	+·00012	+·00005	−·00010	−·00023	−·00031	−·00027

The numbers in the last four lines are curved in Figs. 115 to 118. The curves have a definite and uniform character, which is unlike either that of the diurnal variation of temperature or that of the diurnal variation of horizontal force, but they have the greatest range in winter, the least—almost vanishing—in summer, and an intermediate range in spring and autumn. The residual variation consists mainly of a rapid fall from sunset to midnight and of a slow rise from midnight to sunrise, and it must be regarded as that part of the magnetometer variation which has no counterpart in the variation of horizontal force as shown by the magnetograph or in the variation—contracted and retarded—of the readings of the thermometer. Its constituent elements are probably due (*a*) to the rise of temperature of the magnetometer caused by the placing of the night lamp, so far as this is unaccompanied by a corresponding rise of the thermometer, and the complementary fall of the same temperature in the course of the day; (*b*) to any other variation of the temperature of the magnetometer that does not follow the same law as the variation (contracted and retarded) of the thermometer readings; (*c*) to the slight variation of temperature of the magnetograph so far as this follows some other law than that of the variation (contracted and retarded) of the thermometer readings; and (*d*) to difference (if any) of the variation of horizontal force at the places of the magnetometer and magnetograph. The whole range of the residual variation, of which the night lamp effect is probably the principal element, is equivalent to less than one degree of temperature in winter and less than 0°·3 in summer.

50. To show how very slight the variation of the temperature of the magnetograph must have been, it may be mentioned that in any month of 1872 the greatest mean diurnal range of thermometer readings taken at the hours 6, 10, 14 and 16 was 0°·27; the means for groups of months were—for the winter months 0°·18, for the spring and autumn months 0°·13 and for the summer months 0°·07; and the ranges of the temperature of the magnetometer must have been less than these respective numbers. The equivalent, in force, of the mean diurnal range of temperature for the year (0°·13) of the horizontal force magnetograph is only ·00004 m. m.—m. g.—s unit, a quite insignificant quantity. It may be further mentioned that the greatest mean diurnal range of the temperature of the air of the magnetograph room—as shown by a pair of maximum and minimum thermometers—was in any month except January 0°·7; and in January, when the room was much used for special experiments and more freely ventilated than usual, it was 0°·9.

51. The extent to which the night-lamp effect contributes to the residual variations will, however, be better exhibited in another way. The converted, contracted, lowered or raised and retarded thermometer variations and the amount of the lowering or raising are shown for each month in Table 43:—

TABLE 43.

1872.	HOURS OF COLÁBA CIVIL TIME.												
	0	1	2	3	4	5	6	7	8	9	10	11	12
January ...	—·00023	—·00041	—·00055	—·00067	—·00079	—·00095	—·00111	—·00127	—·00148	—·00156	—·00144	—·00116	—·00080
February ...	—·00001	—·00032	—·00047	—·00052	—·00064	—·00072	—·00084	—·00101	—·00121	—·00132	—·00126	—·00093	—·00056
March ...	—·00009	—·00015	—·00026	—·00031	—·00035	—·00041	—·00048	—·00059	—·00072	—·00082	—·00076	—·00052	—·00022
April ...	—·00006	—·00010	—·00022	—·00027	—·00032	—·00039	—·00048	—·00055	—·00064	—·00070	—·00069	—·00049	—·00023
May ...	+·00018	+·00011	—·00000	—·00015	—·00019	—·00026	—·00033	—·00041	—·00050	—·00054	—·00047	—·00029	—·00004
June ...	—·00004	—·00006	—·00009	—·00008	—·00018	—·00022	—·00029	—·00036	—·00039	—·00045	—·00044	—·00037	—·00026
July ...	—·00005	—·00008	—·00009	—·00011	—·00012	—·00014	—·00016	—·00016	—·00019	—·00021	—·00023	—·00018	—·00009
August ...	—·00020	—·00023	—·00026	—·00028	—·00031	—·00034	—·00037	—·00041	—·00044	—·00044	—·00043	—·00037	—·00028
September ...	—·00010	—·00014	—·00022	—·00029	—·00033	—·00037	—·00040	—·00042	—·00044	—·00045	—·00042	—·00030	—·00014
October...	+·00024	+·00011	—·00004	—·00017	—·00030	—·00043	—·00049	—·00064	—·00074	—·00077	—·00066	—·00042	—·00018
November ...	—·00041	—·00028	—·00039	—·00055	—·00072	—·00087	—·00103	—·00121	—·00139	—·00146	—·00133	—·00102	—·00064
December ...	—·00019	—·00026	—·00033	—·00040	—·00047	—·00056	—·00065	—·00079	—·00090	—·00093	—·00078	—·00054	—·00029

1872.	HOURS OF COLÁBA CIVIL TIME.											Amount by which the 24 hourly inequalities have been raised (+) or lowered (—).
	13	14	15	16	17	18	19	20	21	22	23	
January ...	—·00045	—·00011	+·00021	+·00043	+·00054	+·00052	+·00036	+·00023	+·00009	—·00001	—·00011	—·00045
February ...	—·00019	+·00018	+·00049	+·00074	+·00084	+·00081	+·00064	+·00049	+·00037	+·00026	+·00016	—·00021
March ...	+·00003	+·00024	+·00042	+·00053	+·00054	+·00046	+·00029	+·00011	+·00002	—·00003	—·00007	—·00013
April ...	·00000	+·00021	+·00039	+·00053	+·00056	+·00053	+·00044	+·00025	+·00010	+·00002	—·00002	—·00009
May ...	+·00018	+·00035	+·00050	+·00065	+·00076	+·00079	+·00075	+·00061	+·00043	+·00030	+·00023	+·00011
June ...	—·00009	+·00007	+·00019	+·00032	+·00039	+·00044	+·00042	+·00031	+·00019	+·00006	—·00001	—·00004
July ...	+·00002	+·00010	+·00015	+·00020	+·00020	+·00022	+·00020	+·00017	+·00009	+·00003	—·00002	—·00002
August ...	—·00012	+·00001	+·00015	+·00022	+·00026	+·00025	+·00019	+·00012	—·00001	—·00011	—·00016	—·00015
September ...	+·00002	+·00017	+·00030	+·00040	+·00045	+·00046	+·00035	+·00019	+·00006	—·00002	—·00006	—·00007
October ...	+·00007	+·00031	+·00053	+·00068	+·00082	+·00085	+·00077	+·00060	+·00050	+·00044	+·00036	+·00006
November ...	—·00022	+·00017	+·00062	+·00101	+·00122	+·00121	+·00100	+·00075	+·00058	+·00038	+·00013	—·00017
December ...	—·00007	+·00013	+·00034	+·00054	+·00064	+·00061	+·00049	+·00039	+·00030	+·00017	+·00001	—·00015

The numbers of Table 43 are graphically represented by Figs. 103 to 114, and on the same form are reconstructed Figs. 91 to 102 so as to show not only the increased agreement between the two sets of curves, but also the nature of the discrepancies that still remain. It will be observed that in the figures for November to April the excess force variation curves (Figs. 101, 102 and 91 to 94) rise above the contracted and retarded thermometer variation curves (Figs. 113, 114 and 103 to 106) soon after sunset, and remain steadily above till about sunrise, when, as a rule, a rapid relative descent of the former curves takes place. This implies that the magnetometer was relatively to the thermometer more heated during the hours from sunset to sunrise, and it agrees well with the supposition that it is an effect of the night lamp, but it is not easy to see why the range of this effect should be so much greater in January and February than in the other months as it appears to be.

52. Referring again to the Appendices, Table 164, page [239], last two columns, we find the residual variations for the periods March to October and January, November and December 1872 to be as follows:—

TABLE 44.

Bombay Civil hours.	10	11	12	13	14	15	16	17	18	19	20	21
March to October.	+·00027	+·00053	+·00070	+·00078	+·00074	+·00062	+·00050	+·00027	+·00010	—·00007	—·00014	—·00022
January, November and December	+·00034	+·00079	+·00105	+·00113	+·00132	+·00121	+·00109	+·00092	+·00048	+·00038	—·00001	—·00030

Bombay Civil hours.	22	23	0	1	2	3	4	5	6	7	8	9
March to October.	—·00031	—·00027	—·00034	—·00039	—·00042	—·00043	—·00042	—·00036	—·00043	—·00043	—·00034	—·00002
January, November and December	—·00061	—·00065	—·00069	—·00070	—·00066	—·00070	—·00077	—·00085	—·00097	—·00095	—·00078	—·00019

These are obtained by assuming that the temperature changes of the magnetometer are simultaneous with, and of the same extent as, those of its thermometer—in other words, the case is taken in which the contraction and retardation of our present investigation are both *nil*. The ranges of these residual variations are ·00121 and ·00229, much larger quantities than the ranges, ·00023, ·00042 and ·00079, of the residual variations of the summer, equinox, and winter periods of our present inquiry; and we conclude accordingly that the contracted and retarded thermometer variations represent much more nearly the variations of the temperature of the magnetometer than do the unchanged thermometer variations.

53. Having reached this stage the question arises, are the contractions and retardations that have been found sufficiently definitely related to the ranges of the several months' thermometer variations to justify an attempt to infer their amounts in the years before 1872 from the values of such ranges for the several months of those years? The reply must be that, although the retardation is undoubtedly related to the range of temperature in such a way that it decreases with increase of range, and although the contraction is generally to about two-thirds of the thermometer range, yet the irregularities in the contractions are so little related to the variations of thermometer range that it is unadvisable to depart from the general practice of magneticians by applying corrections to the published variations of horizontal force that would still only greatly diminish, and not completely obliterate, the errors to which these are known to be subject. On the other hand, it would undoubtedly tend greatly to the purification of the variations—at least for the period 1866 to 1872, during which the magnetometer was enveloped by thick quilted cushions, and the contraction and retardation may therefore be assumed to have been similar to those found in 1872—if such corrections, even when only roughly approximate, were applied; and before embodying the results in any investigation such (say) as the application of the harmonic analysis to magnetic diurnal variations this ought to be done. For the years before 1866 (that is from 1846), during which the magnetometer box was exposed directly to the air of the room, such corrections could be applied to the variations with less certainty of effecting the removal from them of only non-magnetic influences than in the later period; but even here it is probable that improvement is possible.

54. But the point which the writer would emphasise, as the principal outcome of this investigation, is that variations derived from readings of the two magnetic force instruments—horizontal force and vertical force—are, when the instruments are subject to considerable diurnal variations of temperature, all affected by large errors owing to the wrong assumption that the thermometer read along with such instruments is a correct indicator of the temperature of the magnetometer. When this fact becomes generally recognised and a common purpose of effecting a partial removal of the errors in question be entertained by practical magneticians, it will be time enough to extend the experiments herein described by entering upon a year's hourly eye-observations of Grubb's horizontal force magnetometer, conjointly with the registrations of the Colába horizontal force magnetograph, during which the magnetometer box should be again directly exposed to the air of the magnetometer room as in the years 1846 to 1866. Until something of this kind is done, the results of all the older investigations of the diurnal variations of horizontal force and vertical force at various points of the surface of the globe must be regarded as unfit for comparison with similar results deduced from the more modern records of instruments that are protected against natural diurnal variations of temperature.

APPENDIX IV.

Effect of heating the Magnetograph Room on the Scale-coefficient of the Vertical Force Magnetograph.

55. In the Appendices to the Bombay Magnetical and Meteorological Observations, 1879-82, page [51] it is explained (in paragraph 73) that towards the end of the year 1878 a portable copper stove with chimney was provided for the purpose of heating the room in which the magnetographs are placed, and that on several occasions coal fires were lighted in the stove, and regulated so as to heat the air in the room and maintain it for a time at a required temperature. This was done successively in the winters of 1878-79, 1879-80 and 1880-81 with a view to determining the effects of change of temperature in altering the registrations of the force magnetographs and of the barograph temperature lever. Another similar heating of the magnetograph room took place on the 30th January 1886, and furnishes further evidence of the same effects, but it was specially designed to test experimentally the conclusion arrived at on pages [42] and [43] of the Appendices above referred to—that an increase of temperature decreases the sensitiveness of the vertical force magnetograph. Two principal sets of deflection observations and three subsidiary sets were made upon the instrument using the magnet E1—the one used in the regular periodical deflection observations—as the deflector, and whilst the instrument was steadily maintained at a nearly uniform temperature: in the principal sets the deflector magnet was placed successively at several different distances from the magnetometer on both the north and south arms of the deflection ring, whilst in the subsidiary sets it was placed only at the distance 2·5 feet and only on the north arm.

In the first principal set, taken on January 29, 1886, and before the heating commenced, the temperature was nearly 86°·7 Fahrenheit; and in the second principal set taken on January 30, during the heating experiment, it was about 105°·0: the subsidiary sets were taken on January 29, January 31 and February 1 with temperatures of 86°·0, 92°·2 and 86°·9 respectively. The mode of exhibiting and treating these observations and that of obtaining the strength-of-field caused by the deflector magnet (acting at its successive different distances) at the place of the magnetometer is set forth in the Appendices above-named—pages [6] to [51]; and we shall—for brevity's sake—indicate the successive steps of the process by marking the several tables that follow with the numbers of corresponding tables in the Appendices.

56. TABLE 45.—*Experimental deflections of the Vertical Force Magnetograph by the deflector Magnet E 1.*

[Corresponding to Table 4 of the Appendices.]

Number and date of experiment.	Local time by Magnetograph Clock.	Vertical Force Magnetograph. Scale reading.	Thermometer.	Vacuum Gauge.	Magnet E 1. Distance in feet.	Magnet E 1. North end.	Observer.	Disturbing force (Y.)	$\frac{Wq}{m}(wo)$	$\left(Y+\frac{Wq}{m}(wo)\right)$
1	2	3	4	5	6	7	8	9	10	11
	d. h. m.									
1.	29 19 42	34·21	86·0	1·81	Away.	...	V. N. and P.	·00000	·00000	·00000
	,, ,, 58	30·81	...	...	2·5 N.	Down.		−·01434	−·00015	−·01449
	,, 20 10	37·60	...	...	2·5 N.	Up.		+·01434	+·00043	+·01477
	,, ,, 19	34·28	86·1	1·81	Away.	...		·00000	·00000	·00000
	,, ,, 29	37·60	...	...	2·5 N.	Up.		+·01434	+·00043	+·01477
	,, ,, 38	30·88	...	...	2·5 N.	Down.		−·01434	−·00015	−·01449
	,, ,, 47	34·11	86·4	1·81	Away.	...		·00000	·00000	·00000

29th January 1886.

TABLE 45—*continued.*

Number and date of experiment.	Local time by Magnetograph Clock.	Vertical Force Magnetograph — Scale reading.	Thermometer.	Vacuum Gauge.	Magnet E 1. Distance in feet.	Magnet E 1. North end.	Observer.	Disturbing force (Y.)	$\frac{Wg}{m}(wo)$.	$\left(Y + \frac{Wg}{m}(wo)\right)$
1	2	3	4	5	6	7	8	9	10	11
	d. h. m.									
II.	29 20 47	34·11	86·4	1·81	Away.	...		·00000	·00000	·00000
	„ „ 56	32·20	...	...	3·0 N.	Down.		−·00822	·00000	−·00822
	„ 21 4	30·80	...	...	2·5 N.	Down.		−·01434	−·00016	−·01450
	„ „ 11	29·70	...	...	2·3 N.	Down.		−·01851	−·00067	−·01918
	„ „ 19	26·29	...	...	2·0 N.	Down.		−·02845	−·00505	−·03350
	„ „ 49	42·67	...	...	2·0 N.	Up.		+·02845	+·00733	+·03578
	„ „ 58	38·99	...	...	2·3 N.	Up.		+·01851	+·00138	+·01989
	„ 22 5	37·83	...	...	2·5 N.	Up.		+·01434	+·00054	+·01488
	„ „ 12	36·24	...	...	3·0 N.	Up.		+·00822	+·00004	+·00826
	„ „ 19	34·20	86·9	1·81	Away.	...		·00000	·00000	·00000
	„ „ 34	32·00	...	...	3·0 S.	Down.		−·00822	·00000	−·00822
	„ „ 42	30·61	...	...	2·5 S.	Down.		−·01434	−·00023	−·01457
	„ „ 50	29·42	...	...	2·3 S.	Down.		−·01851	−·00087	−·01938
	„ 23 0	26·13	...	...	2·0 S.	Down.		−·02845	−·00535	−·03380
	„ „ 11	42·08	...	...	2·0 S.	Up.		+·02845	+·00601	+·03446
	„ „ 19	38·85	...	...	2·3 S.	Up.		+·01851	+·00127	+·01978
	„ „ 27	37·61	...	...	2·5 S.	Up.		+·01434	+·00044	+·01478
	„ „ 34	36·07	...	...	3·0 S.	Up.		+·00822	+·00001	+·00823
	„ „ 42	34·07	86·8	1·81	Away.	...		·00000	·00000	·00000
III.	30 19 42	29·28	104·9	1·89	Away.	...		·00000	−·00096	−·00096
	„ „ 51	27·81	104·9	...	3·0 N.	Down.		−·00822	−·00252	−·01074
	„ 20 1	26·81	104·6	...	2·5 N.	Down.		−·01434	−·00407	−·01841
	„ „ 11	26·10	104·2	...	2·3 N.	Down.		−·01851	−·00541	−·02392
	„ „ 21	24·19	104·5	...	2·0 N.	Down.		−·02845	−·01014	−·03859
	„ „ 32	34·50	104·8	...	1·8 N.	Up.		+·03944	·00000	+·03944
	„ „ 40	32·91	104·8	...	2·0 N.	Up.		+·02845	·00000	+·02845
	„ „ 48	31·51	104·8	...	2·3 N.	Up.		+·01851	−·00004	+·01847
	„ „ 56	30·89	104·7	...	2·5 N.	Up.		+·01434	−·00012	+·01422
	„ 21 5	30·01	104·8	...	3·0 N.	Up.		+·00822	−·00046	+·00776
	„ „ 22	28·70	105·3	1·89	Away.	...		·00000	−·00148	−·00148
	„ „ 34	27·33	105·8	...	3·0 S.	Down.		−·00822	−·00322	−·01144
	„ „ 44	26·33	105·8	...	2·5 S.	Down.		−·01434	−·00498	−·01932
	„ „ 52	25·59	105·8	...	2·3 S.	Down.		−·01851	−·00655	−·02506
	„ 22 2	23·59	105·5	...	2·0 S.	Down.		−·02845	−·01196	−·04041
	„ „ 15	34·13	105·5	...	1·8 S.	Up.		+·03944	·00000	+·03944
	„ „ 24	32·60	105·4	...	2·0 S.	Up.		+·02845	·00000	+·02845
	„ „ 35	31·12	105·1	...	2·3 S.	Up.		+·01851	−·00007	+·01844
	„ „ 43	30·49	104·9	...	2·5 S.	Up.		+·01434	−·00027	+·01407
	„ „ 51	29·60	104·7	...	3·0 S.	Up.		+·00822	−·00074	+·00748
	„ 23 0	28·31	104·3	1·89	Away.	...		·00000	−·00191	−·00191
IV.	31 12 13	29·31	92·2	1·89	Away.	...		·00000	−·00094	−·00094
	„ „ 34	26·39	92·2	...	2·5 N.	Down.		−·01434	−·00486	−·01920
	„ „ 43	31·70	92·2	...	2·5 N.	Up.		+·01434	−·00002	+·01432
	„ „ 53	29·33	92·2	1·89	Away.	...		·00000	−·00093	−·00093
V.	1 4 15	29·80	86·9	1·87	Away.	...		·00000	−·00060	−·00060
	„ „ 34	25·67	86·9	...	2·5 N.	Down.		−·01434	−·00636	−·02070
	„ „ 43	32·69	86·9	...	2·5 N.	Up.		+·01434	·00000	+·01434
	„ „ 50	29·70	86·9	1·87	Away.	...		·00000	−·00067	−·00067

29th January 1886. | 30th January 1886. | 31st January 1886. | 1st February 1886. | V. N. and P.

All the data given in this table were obtained directly by observation except the values of Y, $\frac{Wg}{m}(wo)$ and $\left\{Y+\frac{Wg}{m}(wo)\right\}$ in the last three columns. The values of Y —the disturbing forces produced by the deflector magnet—were calculated in the manner shown in paragraph 40 of the Appendices, the data being obtained from five sets of deflection observations in the horizontal plane taken between the 14th April 1883 and the 19th February 1886. The formula used took the slightly modified form

$$Y=X\alpha\left(1+\frac{H}{F}\right)\frac{D}{2r^3}\left(1+\frac{p}{r^2}\right)$$

and the values of p and D were calculated in the manner spoken of near the end of paragraph 30 of the Appendices.

The data were

$$X=3{\cdot}7406\,;\ \alpha\left(1+\frac{H}{F}\right)D={\cdot}11634\,;\ p=0{\cdot}18450$$

The values of $\frac{Wg}{m}(wo)$ were calculated with the data $W=1802{\cdot}6$ grs.; $g=32{\cdot}108$; $m=0{\cdot}576$; and (wo) for the several scale readings, in order, as follows :—

Scale reading.	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
Value of (wo)*	-358	-276	-205	-145	-96	-58	-30	-12	-2	0	0	0	0	0	+4	+16	+36	+65	+103	+151	+209	+277

* In one hundred millionths of an inch.

together with the factor $\frac{0{\cdot}46108}{12}$ for converting the combination of British measures used into m.m.—m.g.—s. units of force. The values of (wo) are the successive sums of the smoothed values of $\frac{\Delta(wo)}{\Delta s}$ given in column 4*b* of Table 16 of the Appendices.

Lastly, the numbers in the last column are the sums of the respective numbers in the two preceding columns.

57. The numbers in columns 3* and 11 of Table 45 suffice for the calculation, in the manner explained in paragraph 48 of the Appendices, of the values for each experiment of $\left(X+\frac{Wg}{m}c\sin\epsilon\right)\alpha$—the scale coefficient for the division 33·2, and $(C-Y_l)$; these being the invariable quantities, whilst the former numbers are the variable quantities, of equation (10) of the same paragraph 48.

The equation is

$$\left(X+\frac{Wg}{m}c\sin\epsilon\right)\alpha\, s=Y+\frac{Wg}{m}(wo)+(C-Y_l) \qquad (10)$$

and the values found for the constants were as follows :—

TABLE 46.

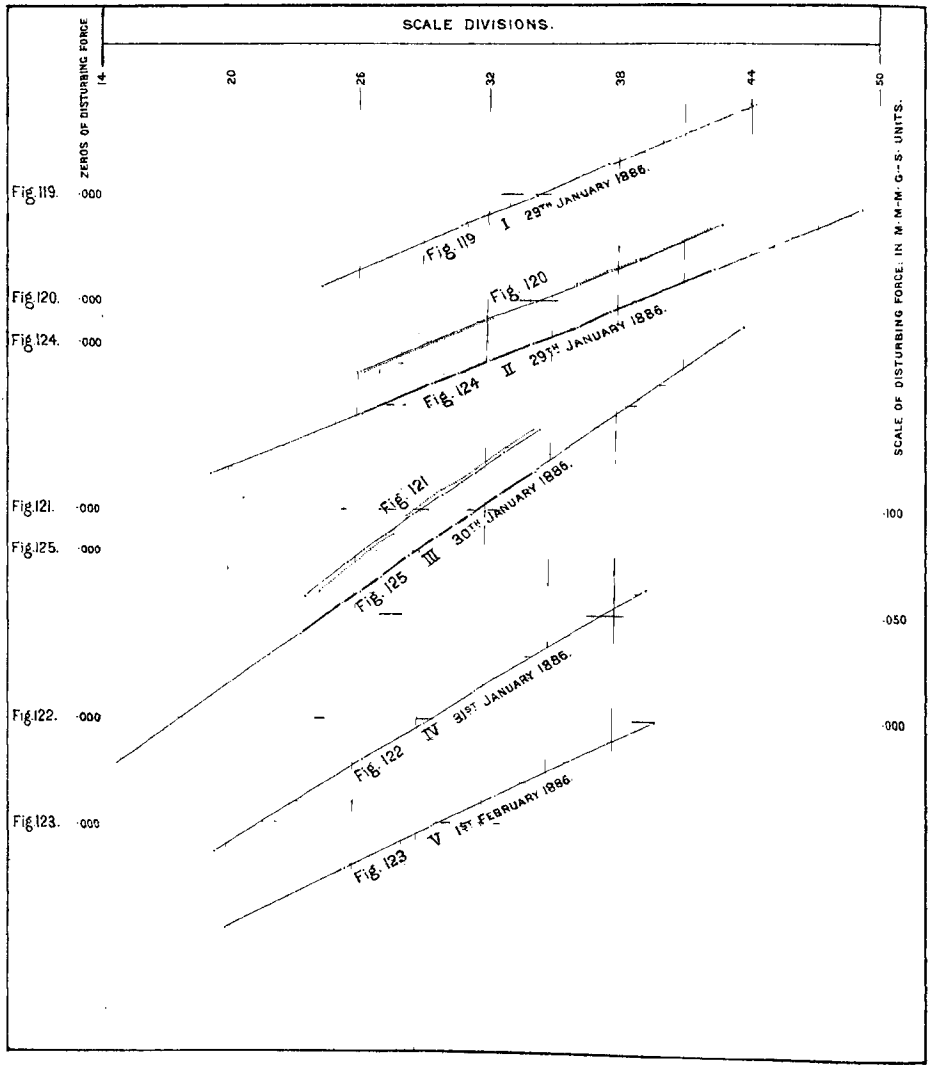
Number of Experiment.	1886.	Thermometer of Vertical Force Magnetograph Mean reading.	$\left(X+\frac{Wg}{m}c\sin\epsilon\right)\alpha$.	$(C-Y_l)$.
1	2	3	4	5
		°		
I.	January 29 ...	86·0	·00433	·14811
II.	„ 29 ...	86·7	·00422	·14405
III.	„ 30 ...	105·0	·00719	·20673
IV.	„ 31 ...	92·2	·00631	·18579
V.	February 1 ...	86·9	·00499	·14389

* For the reason mentioned in the next paragraph the first five scale-readings of Experiment II were diminished by ·04 and the first five of Experiment III by ·97 before being used for these calculations.

COLABA VERTICAL FORCE MAGNETOGRAPH.

SCALE-COEFFICIENTS.

Plate 8



Figures 119 to 125.— See Paragraph 57.

DRAWN ON STONE AND LITHO. GOVT. PHOTOZINCO. OFFICE, POONA, 1888.

Figs. 119 to 123 are constructed to represent the variation of vertical force with change of scale-reading as exhibited by the scale-readings of column 3 (Table 45) and the corresponding disturbing forces of column 11, the latter being laid off as ordinates and the former as abscissæ. It will be observed that the lower left-hand branches of Figs. 120 and 121 are displaced bodily, with reference to the lines of continuity of the upper right-hand branches, to the right: the average displacements are 0·04 and 0·97 scale divisions respectively, and were corrected for, as constant changes of position of the magnet: Figs. 124 and 125 are the mean curves resulting after the application of these corrections. Through the curves of Figs. 119, 122, 123, 124 and 125 are drawn the straight lines represented by the above quoted equation (10) when the constants of the respective lines of Table 46 are introduced into it. The curves are practically coincident with the straight lines as well in the cases of the two long series of deflection observations (II and III) as in those of the three shorter sets (I, IV and V). The important point to consider is, however, the relation of the mean thermometer readings in column 3 of Table 46 to the scale-coefficient in column 4, and especially by comparison of the two principal experiments (II and III). These latter show an increase in the coefficient of ·00297 (=·00719 — ·00422) for an increase of temperature of 18°·3 (=105°·0 — 86°·7), that is increment of scale-coefficient at the average rate of ·000162 per degree; and thus the experiments confirm the conclusion drawn from the regular monthly deflection experiments of February 1881 to June 1882 in its verbal statement (see paragraph 54 of Appendices), though the amount of the increment of scale-coefficient per degree was in that case ·000258. On this point we may remark that the experiments III and IV of Table 46 give an increment per degree of only ·000069, whilst IV and V give a rate of ·000249; that is to say, for small deviations from the normal temperature of the instrument the rate is nearly the same as was found in 1881-82, whilst for large further deviations the rate greatly diminishes. A part of the apparent diminution shown is, however, due to the fact that the coefficients determined by the subsidiary deflection experiments, made *first* at a single distance only of the deflector are systematically greater than those determined by long series of deflection experiments made afterwards, in which the vertical force magnetograph is disturbed through larger arcs, and this holds although the magnetograph is never allowed to *vibrate* through more than a very small arc in either experiment. An instance of this is seen in the excess of the scale-coefficient of experiment I of Table 46 over that of experiment II, and allowing for the 0°·7 of difference of temperature, this excess (of ·00041) is enlarged to about ·00029. But a still greater part of the diminution is probably due to the fact that a part of the increase of the scale-coefficient caused by increase of the temperature of the instrument is permanent, there being no equivalent fall in the value of the coefficient on cooling the instrument; and that of this part the bulk is probably that which is caused by the increments of temperature that lie high in the scale of temperatures, and very little of it by the increments that lie near the normal temperature of the instrument. The excess (·00043) of the scale-coefficient of experiment V (·00499) over that of experiment I reduced to the temperature 86°·9 (·00456) is permanent increase of this kind, due to the intervening heating up to the high temperature of 105°·0.

In the way of physical explanation of the influence of heat on the scale-coefficient the only suggestion of a possibly adequate influence that occurs to us is that the molecules of the vertical force magnet are held together more loosely at high than at low temperatures; that the flexure of the two ends of the magnet under the action of gravity is therefore increased by increase of temperature; and that the centre of gravity of the magnet is thus relatively lower at a given temperature than at a lower temperature. Any "set" that the molecules of the magnet may at first have will, on heating, be weakened and the molecules will under the action of gravity be drawn further down, but the original "set" will fail to be restored on cooling the magnet. Each new heating will thus remove more of the "set" and bring the molecules further down until, in the long run, there is no further yielding of the "set" within the range of variation of temperature to which the magnet is subjected; and from this time increase of cohesiveness of the molecules on cooling will lift them up as much as increased flexure carries them down on heating to the same extent. In this way there should be, as there are in fact, (*a*) an abrupt increase of the scale-coefficient whenever the instrument is raised to a temperature exceeding that to which it has previously been subjected; (*b*) a gradual increase when the temperature oscillates between the moderate limits of the temperature of the instrument in its ordinary use, and (*c*) a *general* increase of the coefficient with increase of temperature and decrease with decrease of temperature, of which (*a*) and (*b*) are the balances that remain in favour of increase of the coefficient when "set" of the molecules remains in the magnet.

58. Under the same general title as the present paper there will appear in the next issue of the Bombay Observations an article which will give an account of the scale-coefficients of the vertical force magnetograph determined from the regular monthly deflection observations made since the month of July 1882. At this time the sensitiveness of the instrument was, at the instance of the International Polar Commission, greatly increased, the objects being to increase the openness of the scale of registration, and to bring the scale into conformity with that agreed upon for the concerted observations of the year beginning with August 1882. These advantages had, it turns out, to be dearly purchased; for the instrument lost so much in steadiness of character that it was no longer practicable to combine together monthly deflection observations that should give to the scale-coefficient nearly so moderate a probable error as before, and that should yet extend over as long a period as before. And the comparatively erratic monthly values of the scale-coefficient that were found under the altered conditions affected, of course, that part of the calculated scale-coefficient which is a function of the temperature of the magnet as well as the constant part and the time element; and hence it arises that the rate at which the scale-coefficient varies with temperature comes out with largely differing values in different periods. The periods into which the monthly observations were divided, in order that no very erratic values of the scale-coefficient should appear in any one group, and the values of the temperature factors found, were as follows:—

TABLE 47.

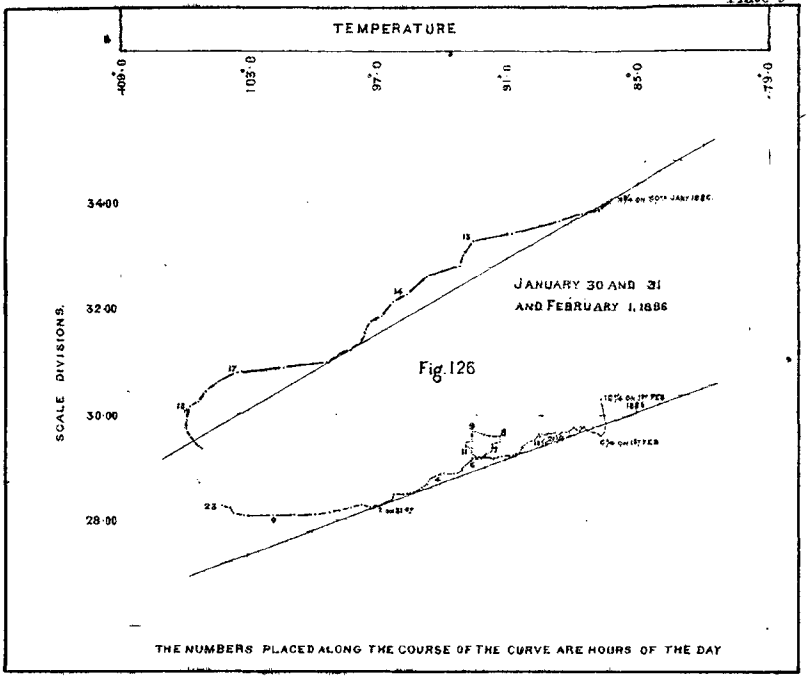
Period.	Temperature factor (b).
August 1882 to April 1883	·000296
May 1883 to January 1884	·000423
February 1884 to February 1885	·000257
April 1885 to October 1885	·000245
November 1885 to January 1886	Rejected.
February 1886 to July 1886	·000437
August 1886 to January 1887...	·000281
Mean.	·000317

Most of the periods chosen fail to run through a cycle of temperature changes, and are thus ill-suited for yielding accurate temperature factors; but they are the best that—in face of general irregularities in the scale-coefficients—were available; and the values they give to the average temperature factor (·000317) is, nevertheless, so much in rough accord with the individual values and so near the formerly adopted value (·000258) as to leave no doubt about the propriety of taking account of it in the reduction of the vertical force magnetograph registrations.

Plate 9

COLABA VERTICAL FORCE MAGNETOGRAPH

HEATING AND COOLING EXPERIMENT



COLABA HORIZONTAL FORCE MAGNETOGRAPH

HEATING AND COOLING EXPERIMENT

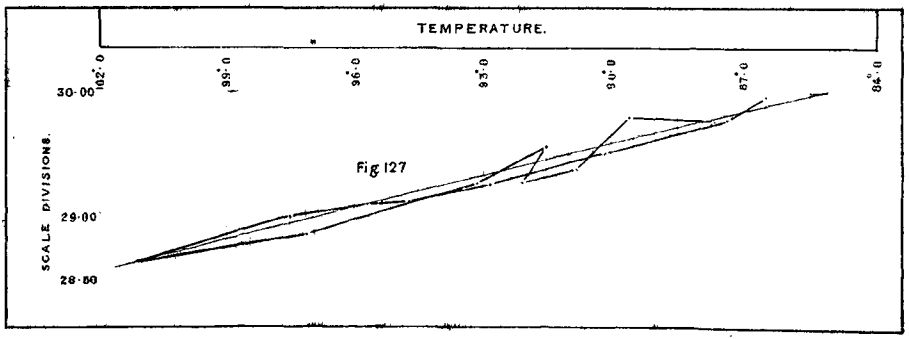


FIGURE 126:—SEE PARAGRAPH 59.

" 127:— " " 63.

APPENDIX V.

Temperature-Coefficient of the Vertical Force Magnetograph.

59. The scale-readings of the vertical force magnetograph before, during and after the heating of the magnetograph room on the 30th January 1886, and the simultaneous readings (in Fahrenheit degrees) of the thermometer placed in the enclosure of that instrument are as shown in Table 48:—

TABLE 48.

[Corresponding to Table 23 of the Appendices.]

Date.	Colába mean time.	Vertical Force Magnetograph. Scale-reading.	Vertical Force Magnetograph. Thermometer.	Date.	Colába mean time.	Vertical Force Magnetograph. Scale-reading.	Vertical Force Magnetograph. Thermometer.	Date.	Colába mean time.	Vertical Force Magnetograph. Scale-reading.	Vertical Force Magnetograph. Thermometer.	Date.	Colába mean time.	Vertical Force Magnetograph. Scale-reading.	Vertical Force Magnetograph. Thermometer.
	h. m.				h. m.				h. m.				h. m.		
29th to 30th January 1886.	10 17a	34·53	85·9	30th January 1886.	14 2	32·33	95·6	30th to 31st January 1886.	17 47	30·26	105·3	31st January 1886.	0 32	28·14	99·9
	14 17	34·51	85·8		14 17	32·16	96·2		18 2	30·16	105·8		0 47	28·18	99·2
	16 17	34·39	85·8		14 32	31·92	96·7		18 17	29·90	105·9		1 2	28·20	98·7
	22 17	34·20	87·0		14 47	31·79	97·2		18 32	29·74	105·9		1 17	28·27	98·1
	6 17	34·11	86·3		15 2	31·62	97·4		18 47	29·60	105·8		1 32	28·30	97·6
	10 17	34·51	86·1		15 17	31·50	97·5		19 2	29·50	105·5		1 47	28·26	97·2
	11 47	34·05	86·2		15 32	31·35	97·8		19 17	29·40	105·3		2 2	28·35	96·7
	12 2	33·93	86·8		15 47	31·22	98·1		19 32c	29·37	105·1		2 17	28·41	96·3
	12 17	33·84	87·6		16 2	31·17	98·8		21 22	28·70	105·3		2 32	28·49	96·1
	12 32	33·70	88·6		16 17b	31·08	98·9		23 2	28·29	104·2		2 47	28·50	95·7
	12 47	33·46	90·7		16 32	31·00	99·2		23 17	28·26	103·9		3 2	28·57	95·2
	13 2	33·28	92·6		16 47	30·90	101·4		23 32	28·17	103·7		3 17	28·64	94·9
	13 17	33·06	93·0		17 2	30·80	103·5		23 47d	28·13	103·1		3 32	28·70	94·7
	13 32	32·84	93·1		17 17	30·60	104·5		0 2	28·11	101·9		3 47	28·81	94·6
	13 47	32·64	94·7		17 32	30·44	105·0		0 17	28·13	100·8		4 2	28·87	94·3
	h. m.				h. m.				h. m.				h. m.		
31st January 1886.	4 17	28·91	93·9	31st January 1886.	8 2	29·60	91·2	31st January 1886.	13 17	29·29	92·5	31st January and 1st February 1886.	20 47	29·70	88·7
	4 32	28·91	93·4		8 17	29·62	91·8		13 47h	29·23	92·4		21 17	29·66	88·6
	4 47	28·98	93·0		8 32	29·66	92·0		14 17	29·21	91·5		22 47	29·68	88·5
	5 2	29·00	93·0		8 47f	29·67	92·1		14 47	29·22	91·1		23 17	29·70	88·3
	5 17	29·04	92·9		9 2	29·69	92·4		15 17	29·27	90·6		0 17	29·73	88·0
	5 32	29·10	92·8		9 17	29·68	92·5		15 47	29·29	90·5		1 17	29·78	87·8
	5 47	29·15	92·7		9 32	29·54	92·5		16 17	29·32	90·3		2 17	29·74	87·5
	6 2	29·19	92·5		9 47	29·52	92·8		16 47	29·40	90·2		3 17	29·80	87·4
	6 17	29·20	92·1		10 2	29·49	92·8		17 17	29·48	90·0		4 17i	29·73	87·2
	6 32	29·28	91·9		10 17	29·40	92·8		17 47	29·57	89·7		5 17	29·68	86·8
	6 47e	29·30	91·7		10 32	29·39	92·7		18 17	29·60	89·6		6 17	29·63	86·7
	7 2	29·39	91·6		10 47	29·39	92·7		18 47	29·60	89·5		7 17	29·73	86·5
	7 17	29·46	91·6		11 2	29·38	92·6		19 17	29·66	89·5		8 17j	29·89	86·4
	7 32	29·54	91·2		11 17	29·38	92·5		19 47	29·67	89·3		10 17	30·35	86·7
	7 47	29·58	91·2		12 17g	29·35	92·5		20 17	29·68	88·9				

a Fire made in the magnetograph room at 11h. 23m. on 30th.

b More coals added at 16h. 17m.

c Deflection observations made from 19h. 42m. to 23h. 0m.

d Removed the fire away between 23h. 40m. and 23h. 58m., and opened the doors and ventilators.

e Double door of room closed at 7h. 53m. on 31st, but ventilators left open as usual.

f Door of lobby closed at 8h. 59m, stopping ventilation from entrance door of underground room.

g Deflection observations made from 12h. 13m. to 12h. 53m.

h All the doors opened at 13h. 37m. and ventilators kept open to cool the room quickly.

i Deflection observations made from 4h. 15m. to 4h. 50m. on 1st February.

j Closed double door restoring usual ventilation of the room at 9h. 0m.

The curve of Fig. 126 has been constructed from the numbers in this table, taking the temperatures as abscissæ and the scale-readings as ordinates and marking the times along the course of the curves. Only one point appears between the times $30^d\ 19^h\ 32^m$ and $30^d\ 23^h\ 2^m$, because deflection experiments were being made during the interval, and the one point corresponds to the position of the vertical force magnet when the deflector magnet was taken away in the middle of the series of experiments.

60. The heating of the room began at $30^d\ 11^h\ 23^m$ and continued till $30^d\ 16^h\ 17^m$ when fresh fuel was added to the fire, and at $30^d\ 23^h\ 40^m$ the fire was carried out of the room and the doors and ventilators were opened: at $31^d\ 7^h\ 53^m$ the double-door of the room was closed, and at $31^d\ 8^h\ 59^m$ the door of the lobby was closed, thereby stopping the ventilation from the upper entrance door of the underground room: at $31^d\ 13^h\ 37^m$ all the doors were again opened and, with the ventilators, left open to cool the room quickly: and finally the double door of the room was closed at $1^d\ 9^h$ leaving the ventilators in action as usual. It will be noticed from Fig. 126 that after the first heating the scale-readings fall at first slowly and afterwards more rapidly; also after the renewed heating at $16^h\ 17^m$ the same occurs: and after the removal of the fire the scale-readings are constant for an hour, then rise slowly for an hour, and afterwards rise steadily at a more rapid rate for several hours: all which implies that the magnet lags behind the thermometer in taking up changes of temperature from the surroundings of the glass shade and gun metal cylinder which enclose them both.* From January $31^d\ 2^h$ to February $1^d\ 8^h$ the curve departs but little from the straight line joining its extremities, except between $31^d\ 7^h\ 2^m$ and $31^d\ 12^h\ 17^m$ when an erratic upward movement occurred that we can only suppose to have been due to change of the vertical force, though the slight increase of temperature after 8^h was doubtless due to the closing of the doors and stoppage of the ventilation. The fall of the curve from $30^d\ 18^h$ to $30^d\ 23^h\ 32^m$ being unaccompanied by further rise of the thermometer must be attributed partly to the lagging of the temperature movements of the magnet behind those of the thermometer, partly perhaps to permanent loss-of-strength of the magnet at the high temperature to which it was raised, and largely to change of "set" of the molecules of the magnet under the same condition. That it is not mainly due to loss-of-strength of the magnet we have the evidence of the experiment made on February 15th—17th, 1879, [see Plate V., Fig. 57 of Appendices] when the temperature was raised equally high and no such permanent reduction of the scale-reading followed; and that it is more likely to be owing to change of "set" we have the parallel case of the experiment of January 24th—27th, 1880, when the instrument had not before been abnormally heated, as now it had not above 97°, since the balancing and compensation weights had last been moved and new strains been thereby introduced into the system of the magnet and its appendages. [See Appendices, paragraphs 59 and 81.]

61. It thus happens that permanent fall of scale-reading is so mixed up with rise and fall due to corresponding rise and fall of temperature between $30^d\ 16^h\ 17^m$ and $31^d\ 2^h$ that no use can be made of that part of the experiment for the purpose now contemplated; and for the rest, the best that can be done is probably to suppose that the permanent fall affects as much the rate of fall of the curve with rise of temperature (fom $30^d\ 11^h\ 47^m$ to $30^d\ 16^h\ 17^m$) in one direction as it affects the rate of rise of the curve with fall of temperature (from January $31^d\ 2^h\ 2^m$ to February $1^d\ 8^h\ 17^m$) in the other direction; or, drawing straight lines on the curve between the extremities of the fall and of the rise, to assume that the mean rate of these lines is the temperature coefficient in scale divisions *per* degree. The rate corresponding to the first line is — 0·238, that of the second — 0·151, and the mean of the two is — 0·194: or converted into force by the factor (·0060)† appropriate to the mean scale division of the two straight lines and the mean temperature (94°·5) it becomes — ·00116 m. m. — m.g. — s. unit of force. The value of this quantity found on February 23rd—26th, 1881, when the only known difference in the condition of the vertical force magnetograph was that its centre of gravity was slightly lower, was ·00016 [see Appendices, Table 24]. The change to seven times its former amount of the temperature-coefficient, apparently by molecular actions that accumulate effect by the mere lapse of time, brings to light a new difficulty in turning to useful account the registrations of the vertical force magnetograph. It is no longer safe to ignore even the very small diurnal variations of temperature to which the instrument is subject, nor yet does it seem practicable to determine the diurnal variation of the temperature of the magnet, ranging as it does much within that of the air of the magnetograph room (0°·4), or to find temperature coefficients that may, under the circumstances, be deemed accurate enough and steady enough for application—in the usual manner—as constants. Our practice hereto-

* This inference is as much strengthened in the case of the first heating as it is weakened in the case of the cooling by the fact that the scale-coefficient increases with increase of temperature.

† It would be more exact to convert small increments of scale-divisions into equivalents of force by applying coefficients which vary properly with the scale-division, and with temperature, but the refinement is unnecessary in the present case.

fore has been to determine diurnal variations of the uncorrected registrations of the vertical force magnetograph, and to keep in mind the fact that the results are not purely magnetic variations, but are contaminated by admixture with a temperature variation; and upon this practice we do not, at present, see our way to improve. It is certain that the adulteration of the magnetic variation must have been very much less after February 1881 than in February 1879 or in February 1886; but the advantage was obtained at such a considerable sacrifice of continuity of the record, and is apparently so liable to disappear by spontaneous change to which the instrument is subject, that it is doubtful whether a single instrument is competent to afford a nearly continuous record of satisfactory character. We are not aware whether other vertical force magnetographs have been found to possess the imperfections of the Colaba instrument; but if so, it would seem that two instruments are necessary to afford a complete record, either one of which could be stopped for fresh adjustment whilst the other kept up the supply of continuous curves.

62. The readings of the vacuum gauge, within the vertical force magnetograph enclosure, varied during the heating experiment between 1·82 and 1·89 inches of mercury.

APPENDIX VI.

Temperature-Coefficient of the Horizontal Force Magnetograph.

63. The readings shown in the following table are those of the horizontal force magnetograph —first as observed, and then as corrected for change of horizontal force—taken before, during and after the heating of the magnetograph room on the 30th January 1886. The corrections were found from readings of Grubb's horizontal force magnetometer taken simultaneously up to $30^d\ 23^h\ 34^m$ and four minutes earlier than the readings of the magnetograph after that time.

TABLE 49.

[Corresponding to Table 36 of the Appendices.]

Date.	Colāba mean time.	Horizontal Force Magnetograph. Scale-reading. Observed.	Scale-reading. Corrected for change of H. F.	Scale-reading. Mean of group.	Thermometer. Observed.	Thermometer. Mean of group.
1	2	3	4	4a	5	5a
29th and 30th January 1886.	h. m.					
	10 19	32·58	30·05	29·98	86·6	86·5
	14 19	31·72	29·92		86·5	
	16 19	31·42	30·15		86·4	
	22 19	31·70	29·81		86·9	
	6 19	31·83	30·07		86·4	
	10 19a	32·05	29·89		86·3	
	11 49	32·07	29·83	29·79	86·9	87·4
	12 4	31·99	29·76		87·0	
	12 19	31·93	29·75		87·6	
	12 34	31·94	29·81		88·1	
	12 49	31·87	29·61	29·52	89·5	90·1
	13 4	31·70	29·54		90·0	
	13 19	31·68	29·47		90·3	
	13 34	31·71	29·47		90·6	
	13 49	31·53	29·35	29·27	91·7	92·8
	14 4	31·38	29·27		92·6	
	14 19	31·22	29·23		93·0	
	14 34	31·12	29·23		93·8	
	14 49	30·84	29·20	29·14	94·0	94·7
	15 4	30·52	29·14		94·7	
	15 19	30·62	29·13		95·0	
	15 34	30·58	29·09		95·2	
	15 49	30·62	29·11	29·11	95·4	95·7
	16 4	30·61	29·13		95·7	
	16 19b	30·56	29·10		96·1	
	16 34	30·60	29·12	29·01	96·4	97·5
	16 49	30·11	29·03		97·7	
	17 4	29·71	28·88		98·5	
	17 19	29·59	28·76	28·66	100·1	101·2
	17 34	29·35	28·62		100·2	
	17 49	29·10	28·54		100·7	
	18 4	28·89	28·62		100·9	
	18 19	29·24	28·67		100·9	
	18 34	29·38	28·74		101·0	
	18 49	29·31	28·74		101·0	
	19 4	29·30	28·76		101·1	
	19 19	29·29	28·77		101·0	
	19 34	29·33	28·73		101·1	
	19 49	29·56	28·70		101·0	
	20 4	29·65	28·71		100·9	
	20 19	29·54	28·65		101·0	
	20 34	29·40	28·65		101·2	
	20 49	29·53	28·70		101·3	
	21 4	29·70	28·68		101·4	
	21 19	29·65	28·63		101·7	

Date.	Colāba mean time.	Horizontal Force Magnetograph. Scale-reading. Observed.	Scale-reading. Corrected for change of H. F.	Scale-reading. Mean of group.	Thermometer. Observed.	Thermometer. Mean of group.
1	2	3	4	4a	5	5a
30th and 31st January 1886.	h. m.					
	21 34	29·77	28·63	28·88	101·8	97·1
	21 49	29·73	28·60		102·1	
	22 4	29·74	28·56		102·0	
	22 19	29·70	28·59		102·0	
	22 34	29·80	28·53		101·9	
	22 49c	29·70	28·48		101·8	
	23 4	29·86	28·67		101·4	
	23 19	29·83	28·59		101·1	
	23 34	29·90	28·61		101·0	
	23 49	30·20	28·85		100·8	
	0 4	30·35	28·93	29·58	99·9	91·5
	0 19	30·02	28·68		99·1	
	0 34	30·24	28·82		98·4	
	0 49	30·45	29·11		98·1	
	1 4	30·40	28·89		97·5	
	1 19	30·31	28·70		97·2	
	1 34	30·28	28·75		97·0	
	1 49	30·58	28·94		96·3	
	2 4	30·72	28·68		95·8	
	2 19	30·82	28·96		95·5	
	2 34	30·70	28·92		95·2	
	2 49	30·68	29·17		95·0	
	3 4	30·61	29·10	29·28	94·8	93·1
	3 19	30·78	29·36		94·5	
	3 34	30·93	29·24		94·3	
	3 49	30·82	29·17		94·0	
	4 4	30·75	29·32		93·7	
	4 19	30·62	29·14		93·4	
	4 34	30·60	29·33		93·1	
	4 49	30·61	29·18		93·0	
	5 4	30·73	29·36		93·0	
	5 19	30·80	29·26		92·9	
	5 34	30·82	29·23		92·7	
	5 49	30·83	29·19		92·2	
	6 4	30·96	29·27		92·2	
	6 19	31·11	29·42		92·0	
	6 34	31·10	29·34		92·0	
	6 49	31·10	29·56		91·9	
	7 4	31·19	29·44		91·7	
	7 19	31·25	29·58		91·6	
	7 34	31·39	29·67		91·2	
	7 49d	31·43	29·70		91·2	
	8 4	31·40	29·67		91·2	
	8 19	31·40	29·65		91·5	
	8 34	31·35	29·52		91·7	

Date.	Colāba mean time.	Horizontal Force Magnetograph. Scale-reading. Observed.	Scale-reading. Corrected for change of H. F.	Scale-reading. Mean of group.	Thermometer. Observed.	Thermometer. Mean of group.
1	2	3	4	4a	5	5a
31st January and 1st February 1886.	h. m.					
	8 49e	31·39	29·45	29·40	91·9	90·8
	9 4	31·41	29·39		92·1	
	9 19	31·49	29·34		92·1	
	9 34	31·52	29·31		92·1	
	9 49	31·48	29·29		92·1	
	10 4	31·49	29·25		92·2	
	10 19	31·60	29·29		92·2	
	10 34	31·65	29·28	29·30	92·2	92·1
	10 49	31·78	29·36		92·2	
	11 4	31·80	29·29		92·2	
	11 19	31·79	29·23		92·1	
	12 19	31·73	29·27		92·0	
	13 19	31·51	29·28		91·9	
	13 49f	31·42	29·38		91·8	
	14 19	31·31	29·37	29·40	91·4	91·1
	14 49	31·18	29·38		91·1	
	15 19	31·00	29·43		90·7	
	15 49	30·91	29·43		90·4	
	16 19	31·09	29·64	29·82	90·3	89·6
	16 49	31·12	29·72		90·2	
	17 19	31·17	29·74		90·1	
	17 49	31·25	29·69		90·0	
	18 19	31·24	29·86		89·8	
	18 49	31·32	29·97		89·7	
	19 19	31·36	29·90		89·6	
	19 49	31·39	29·96		89·4	
	20 19	31·39	29·94		89·0	
	20 49	31·40	29·81		89·0	
	21 19	31·40	29·81		89·0	
	22 49	31·34	29·69	29·78	88·8	87·7
	23 19	31·30	29·69		88·6	
	0 19	31·35	29·79		88·3	
	1 19	31·39	29·69		88·1	
	2 19	31·70	29·79		87·9	
	3 19	31·71	29·77		87·8	
	4 19	31·61	29·72		87·3	
	5 19	31·43	29·70		87·1	
	6 19	31·60	29·80		87·1	
	7 19	31·80	29·88		86·9	
	8 19g	32·03	30·04		86·9	
	10 19	32·24	29·86		87·1	

a Fire made in the magnetograph room at 11h. 23m. on 30th.
b More coals added at 16h. 17m.
c Removed the fire away between 23h. 40m. and 23h. 58m. and opened the doors and ventilators.
d Double door of room closed at 7h. 53m. on 31st, but ventilators left open as usual.
e Door of lobby closed at 8h. 50m. stopping ventilation from entrance door of underground room.
f All the doors opened at 13h. 37m. and ventilators kept open to cool the room quickly.
g Closed double door, restoring usual ventilation of the room at 9h. 0m. on 1st February.

The air within the glass-shade enclosure of the horizontal force magnetograph was throughout at the natural pressure of the atmosphere.

The numbers of columns 4*a* and 5*a* are curved in Fig. 127. Periods of steady temperature, from which to determine the temperature coefficient, were selected as follows :—

TABLE 50.

[Corresponding to Table 32 of the Appendices.]

Period:			Horizontal Force Magnetograph.				
Month.	Beginning.	End.	Scale-reading corrected to a constant value of the horizontal force.	Differences.	Thermometer.	Differences.	$\frac{\Delta s}{\Delta t}$
1	2	3	4	5	6	7	8
	d. h. m.	d. h. m.					
January 1886...	29 10 19	30 10 49	29·98		86·5		
				1·32		14·7	
„ „ ...	30 17 19	30 23 49	28·66		101·2		
				0·71		9·3	•
„ „ ...	31 8 4	31 14 49	29·37		92·9		
				0·46		4·8	
February 1886	1 4 19	1 10 19	29·83		87·1		
Sums and quotient				2·49		28·8	·0865
Corresponding means			29·28		94·0		
Temperature coefficient $= \frac{dX}{ds} \frac{\Sigma \Delta s}{\Sigma \Delta t} =$ ·00362 × (−·0865) = −·000313							

The resulting value (—·000313) of the temperature coefficient agrees almost exactly with the mean value (—·00032) yielded by the five experiments dealt with in paragraph 111 of the Appendices.

The straight line of Fig. 127 is drawn through the point corresponding to the scale division 29·91 and the thermometer reading 86·5 and with the direction corresponding to the value of $\frac{\Delta s}{\Delta t}$ ·0865. It is that which passes nearest to the four points represented by the four pairs of numbers of columns 4 and 6 of Table 50.

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